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AN INTERACTIVE LIFE CYCLE COST
FORECASTING TOOL

THESIS

David L. Sumner
First Lieutenant, USAF

AFIT/GOR/ENS/90M-17

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AN INTERACTIVE LIFE CYCLE COST FORECASTING TOOL

THESIS

Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

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In Partial Fulfillment of the

Requirements for the Degree of

Master of Science

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David L. Sumner, B.S.

First Lieutenant, USAF

March 1990

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Preface

I chose this research topic because of my interest in Monte Carlo simulation and statistical description. I am indebted to Dr. J.P. Cain for presenting such an interesting opportunity, and for giving me the economics background to deal with it.

Also, sincerest thanks are in order to Maj Ken Bauer for helping me to ensure statistical integrity in all the sampling and descriptive procedures.

I am forever indebted to wife, Tammy, and my family for their love and support.

David L. Sumner

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List of Abbreviations

APR - Annual percentage rate
CDF - Cumulative Density Function.
CER - Cost Estimating Relationship
CI - Confidence Interval
CON - Length of constant cost period
CR - Carriage return
GLD - Generalized Lambda Distribution
LCC - Life Cycle Cost
LRU - Line replaceable unit
MSE - Mean Square Error
PC - Personal Computer
PDF - Probability Density Function
PI - Length of Phase in period
PO - Length of Phase out period
PV - Present value

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Abstract

A tool was developed for Monte Carlo simulation of life cycle costs using parametric cost modeling. Additionally, the analysis of the performance of parametric CER cost estimation has been cut down to a more manageable task. Models can be built and tested quickly and easily.

Random deviate generators were researched and built. Several applicable statistical descrption routines were also implemented. Statistical integrity and great accuracy has been maintained, while made accessible through an intuitive, user friendly interface.

AN INTERACTIVE LIFE CYCLE COST FORECASTING TOOL

I. Introduction

Background

Each year the United States government spends billions of dollars for manpower and equipment to protect and preserve the nation. As important as national defense is, it is only one of many ways the government serves the people. Programs such as education, transportation, and human assistance are also necessary parts of government spending.

Unfortunately the government is not endowed with unlimited resources. Each program is in constant competition with others for funding. Indeed a large part of our political system is dedicated to the parsing and distribution of tax dollars. Since the government is tasked with performing many services with limited resources, it is compelled to get the most from each tax dollar spent. Since many of the dollars spent on national defense go toward acquiring new weapon systems, the government should buy the least expensive piece of hardware capable of doing the job, or buy the best piece of hardware while staying within the budgetary constraints. The latter case, maximizing efficiency can be demonstrated by the simple optimization problem below:

$$\text{Max } E = F(A,B) \tag{1}$$

$$\text{st. } C = C_A + C_B \tag{2}$$

Where C_A and C_B are cost functions, linear or nonlinear, for Systems A and B. These cost functions may be based on quantity purchased. C is a budgetary constraint, and E is some production function representing the combined performance of systems A and B. Note that this is for a given configuration. The E represents effectiveness and is equated to some function of the quantity of systems A and B purchased.

Either strategy, maximizing effectiveness or minimizing cost, leads to some type of cost comparison among the proposed systems. The problem is that new weapon systems do not come off the shelf with clear cut price tags. The cost of each program must be estimated, then compared with the other programs in question. It is easy to see that realized efficiency depends greatly on the quality of the cost estimation.

Fisher, as well as others, has suggested that to properly estimate the budgetary impact of a particular system, all phases of the program must be examined (Fisher:66). Purchase price alone does not constitute the system cost. There are research and development, testing, procurement, operation, and maintenance phases that must be considered. All spending associated with a program is called the life cycle cost (LCC). The DoD Life Cycle Costing Guide For System Acquisitions defines LCC.

> The LCC system is the total cost to the Government of acquisition and ownership of that system over its full life. It includes the cost of development, acquisition, operation, support and where applicable, disposal. (DoD:1-1)

Life cycle costing has several advantages over simple purchase price estimation. Since life cycle costing includes all the phases of the program's life, a more realistic look at the budgetary effect is achieved. Figure 1 demonstrates the large portion of DoD funds used for operation and support, costs not included in the purchase price. It is very possible that system A may have a lower purchase price than system B, but have such a large manning and support requirement that these costs overwhelm the purchase price and make B a more economical choice.

Since the stages of the program occur chronologically, LCC also allows for the "timing" of the money spent. Banks exist and flourish all over the world profiting almost exclusively from the time value of money. So the timing of money spent by competing programs can be a very significant factor.

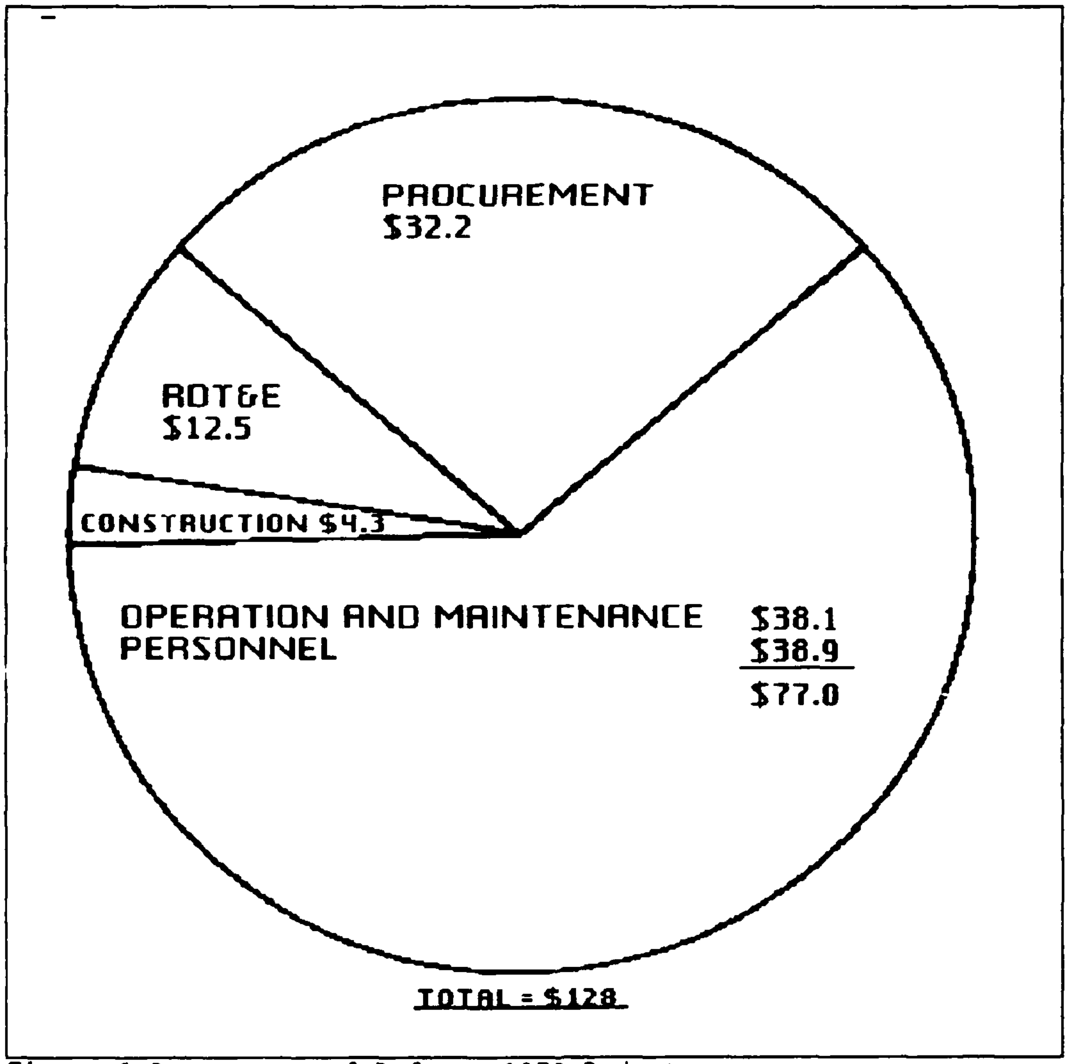


Figure 1 Department of Defense 1979 Budget
Billions of Dollars (Seldon:2)

Objective

The objective of this research is to develop an easy to use, flexible, PC-based Monte Carlo simulation for the preliminary estimation or forecasting, of life cycle costs.

Subobjectives

Model Definition. The first step is to survey life cycle cost models by reviewing literature. Identification of the proper model must precede all other steps.

Model Construction. Construction of the mathematical model, which means creation of the source code, is the next step in using the LCC cost model chosen. The actual mathematical calculations must be coded in this step.

It will be necessary to develop random number generators, the basis of the Monte Carlo simulation. Development of fast, competent generators is crucial to achieving the overall objective.

Software for the analysis of the LCC outputs must also be developed. The next section of code is the LCC distribution identification routines. Quantile estimation is closely linked to distribution identification, and it must also be coded.

Software Production. After verification of the various mathematical software routines, these routines must be integrated into a single program with a logical, flexible control structure. The integration of the routines is no more important than the development of a user friendly interface. The program must be easy to use.

Documentation. The documentation must be polished up and formatted. This documentation must include a User's Manual.

II. LITERATURE REVIEW

Introduction

The goal of this research is to design and build a flexible, easy to use tool for Monte Carlo simulation of the life cycle costs of weapon systems, including estimation of the distribution of these costs. Monte Carlo simulation is simply a compilation of random generations aggregated to infer something about the real world. The tool must generate samples from a cost distribution according to historic data about past weapon system attributes and costs. The areas of literature that must be reviewed for this effort include theoretical life cycle costing models, statistical estimation, and random number generation.

Chapter Overview

This chapter will present a brief overview of the types of LCC models available in the literature, providing the characteristics of each model, good and bad.

Since Monte Carlo simulation involves the representation of random events, the random number generator used by the modeling program must generate numbers that actually appear to be random. This chapter will review promising methods for generating the random numbers needed by the life cycle cost model. Sample output from the random deviate generators actually used can be found in Appendix B.

LCC Modeling

The literature suggests that there are basically three types of LCC models (Collins:55; Krisch:1527; Seldon:161; DoD:3-3):

1) Parametric cost factor models
2) Engineering cost factor models
3) Accounting models

Parametric. The parametric cost factor model is named so "because the physical and performance measures are commonly called parameters in the estimating equations" used to forecast costs (DoD:3-3). The weight or number of engines on an aircraft may be used, for instance, to estimate the production and operating costs. Krisch explains that curve fitting can be used to derive Cost Estimating Relationships (CER) between cost and production schedule and system characteristics. These CER's can be adjusted to make the best estimate possible from past data (Krisch:1527).

Several advantages are associated with using this type of cost estimation, as outlined by the DoD Life Cycle Costing Guide For System Acquisitions:

1) Cost estimates are based on general system characteristics, no detailed information is necessary;

2) Model is very fast and easy to use;

3) Model is resistant to user bias;

4) Since parametric statistics are used in generating the forecasts, confidence intervals (CI's) can be placed on the forecasts (DoD:3-6).

It is in this last advantage that lies the real power of this type of modeling.

Figure 2 shows an example of a parametric CER model. Notice that the costs are being calculated from general characteristics, and that there is some error associated with each equation.

Engineering. Many authors ignore this model or group it with the model above in the "cost factor" category (Krisch:1527; Collins:54). This is because the engineering model is very similar to the parametric CER model mechanically. The system is broken down into cost components like above, and cost relationships are used to determine the cost of each component.

The difference in the CER and engineering models lies in the type estimating relationships used. The model above uses relationships of convenience, which may or may not capture a great deal of the cost variance. The engineering model uses specific hardware-to-cost relationships to

COST REPRESENTATION FOR 1 C-130

CER's

AIRFRAME	$= 200{,}000 + 75\,X_1 + e$
ENGINES	$= 2{,}000 + 63\,X_2 + e$
ELECTRONICS	$= 530 + 200\,X_3 + e$
MANPOWER	$= 300{,}000 + 400{,}000\,X_4 + e$
OPS	$= 500{,}000 + 12{,}000\,X_5 + e$

WHERE

X_1 = airframe weight
X_2 = thrust
X_3 = number radios
X_4 = crewmembers
X_5 = yearly flying hours
e = error, iid N(0,MSE)

Figure 2 Parametric CER cost model example.

determine cost. Obviously this takes more information, and indeed DoD does not recommend this as a method for preliminary work since the level of detail needed is usually obtained after many crucial decisions (based on cost) have been made (DoD:3-12). The main advantages of this method are increased accuracy and hence more detailed sensitivity analysis of differing configurations, and ease of transition from a CER model (DoD:3-11).

Figure 3 is an example of an engineering model. Notice that the cost equations are more detail than in the CER model. Also the cost equations do not have the same error

COST REPRESENTATION FOR
1 C-130

cost equations

AIRFRAME = $13\,X_1 + 109\,X_2 + 12\,X_3 + 2.5\,X_4 + .03\,X_5 + 750\,X_6$

ENGINES = $150{,}000\,X_7 + 520\,X_8 + 3700\,X_9 + 6200\,X_{10}$

WHERE

X_1 = ribs in feusalage
X_2 = windows
X_3 = aluminum sq. ft.
X_4 = pipes ft.
X_5 = rivets
X_7 = hydraulic pumps
X_7 = compressors
X_8 = fuel pumps
X_9 = propellors
X_{10} = fuel filtration systems

Figure 3 Engineering cost model example.

associated with the CER's because these cost equations <u>are</u>

the real world relationships between physical construction and cost.

Accounting. This seems to be the most detailed of the models types, summing costs over system components at a very low level, taking into account such needs as personnel, training, etc. This methods takes an enormous amount of information, such as lists of "contractor supplied LRU's ... flying hour programs and development scenarios ... Labor rates, inventory costs and repair cycles times, for example" (Collins:55).

Figure 4 shows an example of a portion of an accounting model. Notice that subsystems must be accounted for at a very low level. This would continue until virtually every part in the aircraft, and all the service costs, have been accounted for.

The reader may notice that the different types of models seem to be a progression of more and more detailed cost models. For this reason there seems to be a consensus among authors that the less specific models are more useful early in the acquisition cycle when little is known about the proposed system (Collins:56; DoD:3-10; Krisch:1527).

COST REPRESENTATION FOR 1 C-130

AIRFRAME

rivets	door adjustment	door seals
screws	hydraulic pumps	carpet
windows	hydraulic lines	boosters
floor board	interior lights	light bulbs
hinges	throttle cables	yoke
seats	hydraulic valves	insulation
wire	manual switches	
⋮	⋮	⋮

AIRFRAME
⋮
\+ ______________
total cost

Random Number Generation

This portion of the literature review is concerned with the generation of random numbers, the simulation of samples conforming to a given cumulative density function. A cumulative density function (CDF), or distribution, is simply a function that makes a generalization about a population of values. Given an initial value, the CDF will identify the probability that a number drawn at random from the specified distribution (or population of numbers) will be smaller than the initial value:

$$CDF(X) = P(x \le X) \tag{3}$$

A number drawn at random from the population is called a random deviate since we don't know exactly what its value will be, or how far it will deviate from the expected value. Random deviates are useful because they allow modelers to sample from real-world processes.

Computer programming is by nature very structured, making the generation of random numbers no trivial matter. Winchmann and Hill offer the following from von Neumann, "Anyone who considers arithmetical methods of producing random digits is, of course, in a state of sin" (Winchmann:127). Since any numbers generated by the methods to follow are reproducible by rerunning the same code again, they are not truly random. These numbers are called pseudo random deviates. These pseudo random deviates can be just as effective as truly random deviates if the generation method is designed with care, and the reproducibility they allow can be an aid in experimentation.

General Sampling Techniques. There are various methods for generating samples from some specified distribution.

The following methods were drawn from Pritsker, but they are commonly found in the literature (Pritsker:707):

1) Inverse transformation

2) Rejection

3) Composition

Ross adds another general technique, also common in the literature (Ross:442):

4) Hazard rate

Inverse Transformation. Pritsker makes it clear that the inverse transformation, or inverse CDF method, is by far the easiest method to use (Pritsker:708). This method entails using a function that is the inverse of the CDF function to generate properly distributed variables. Since the CDF returns a probability (between zero and one) associated with some value, the inverse CDF begins with a number between zero and one to produce the value associated with the given level of probability. Since the CDF of the distribution in question must be invertible, this method is not applicable for some of the commonly used distributions. Like all other methods discussed in this section the inverse transform method requires the generation of numbers uniformly distributed between zero and one. A simple uniform random number generator (U[0,1]) may be found in Winchmann et al (not used here), but the construction of

U(0,1) generators is not the subject of this section (Winchmann:127-128).

Rejection. Tadikamalla gives a very good summary of the rejection method, also known as acceptance-rejection, as developed by Von Neumann (Tadikamalla:925-928). Rather than using the CDF described above, rejection makes use of the PDF associated with the distribution being modeled. The PDF is the first algebraic derivative of the CDF. The area under the PDF curve, taken between two points, gives the probability that a randomly drawn value will lie between the two points. The key is to find some other function, whose value returned for a given zero-one number will always be larger the value of the PDF at the same point. This is known as a majorizing function. This majorizing function must be easy to sample from (by inverse CDF or some other method).

A uniform zero-one variate and a variate from the majorizing function are drawn. If the uniform variate is smaller than the ratio of majorizing function value to PDF value, keep the variate as a sample from the designated distribution, otherwise draw new variates and try again. It stands to reason that the closer the majorizing function and the real PDF are, the fewer variates are rejected; so the smaller the difference between PDF and majorizing function, the more efficiently random numbers are generated (Tadikamalla:925-928).

Composition. This method may be used when the density function can be written as a weighted sum of other distributions (with the sum of weighting factors totaling one [Pritsker:710]). To sample from the designated distribution, fist sample from the component distributions and sum according to the weighting factors to create one random variable.

Hazard Rate. The hazard function (H) is defined as the ratio of the PDF to the CDF (Ross:442):

$$H = PDF/CDF = P(t < x < t + dt \mid x > t) \qquad (4)$$

This specifies the probability of a random variable x being greater than some value t + dt given that x is greater than t. Leemis (Leemis:892-894) as well as others recognize that the hazard function for any probability distribution has unit exponential distribution, a known probability structure. The inverse of this hazard rate can be used to generate random variables similar to the inverse transformation method.

There are other methods for generating random variables that make use of the special properties of particular distributions. Special algorithms have been developed for sampling from most of the commonly used distributions which are faster than the general techniques. While Pritsker (Pritsker:710-711) gives a tidy outline of these, only the methods applicable to the distributions needed for this research will be discussed in the next section. Also outlined by Pritsker is the idea that there may be useful working relationships among the various methods for generating random variables.

> ... the composition method may employ the inverse transformation method to select a subdistribution and then any sampling procedure to obtain a random sample from the subdistribution. The acceptance/rejection method is frequently used where majorizing functions are defined for portions of the distribution function. Thus, it should be clear that the methods for generating random samples are not necessarily used independently.(Pritsker:710)

<u>Specific Generation Techniques</u>. Since the majority of the random numbers needed for life cycle cost estimating must be distributed according to the beta distribution, this section will focus on generating beta deviates. The beta is useful for modeling symmetric or skewed unimodal data. The beta differs from the normal by the lack of long tails that extend out to positive and negative infinity, enabling the representation of populations having discrete upper an lower limits. Unfortunately the CDF of the beta distribution cannot be inverted, so the inverse CDF method is of no use. Furthermore, the combination of the first four moments of the beta make it very difficult to sample from by any method. For that reason the literature is mainly concerned

with the generation of two-parameter beta variates as the ratio of two-parameter gamma variates. Ross offers the following formula for obtaining a beta variable with parameters n and m (Ross:452):

$$\text{Beta}(n,m) = \text{Gamma}(n,1)/\ (\text{Gamma}(n,1)+\text{Gamma}(m,1) \qquad (5)$$

The parameters are often noted as (α,β) elsewhere in the literature.

Fishman provides a comparison of his improved method for generating gamma deviates to the algorithm of Wallace, developed earlier. The following is Wallace's algorithm as reported by Fishman:

> For integral α method 2 uses (7) [see paragraph below]. For non-integral α the six steps are:
> 1. Generate a uniform deviate U.
> 2. If $U <= 1 - \alpha + < \alpha >$ then generate X' from (7) using $b=<\alpha>$.
> 3. Otherwise, generate X' from (7) using $b= <\alpha + 1>$.
> 4. Generate a uniform deviate U.
> 5. If $U <= (X'/t')\ t'\ /\ (1-t'+t'X'/t)$ then X' has the pdf in (2).
> 6. Otherwise, go to step 1. (Fishman:408)

where t is $<\alpha>$, the largest integer contained in α, and t' is α-t. Fishman's (7) refers to the negative natural log of a multiplicative sum of α uniform deviates, the standard method for calculating integral parameter gammas (Fishman:408;Tadikamalla:925;Wallace:693):

$$-\mathrm{Ln} \prod_{i=1}^{<\alpha>} U(0,1)_i \tag{6}$$

while (2) refers to (Fishman:407):

$$\begin{aligned} f\,x\,(X,\alpha,\beta) &= c(\alpha,\beta)a(\alpha,\beta)g(X,\alpha,\beta)h(X,\alpha,\beta) \quad 0 \le X \le \infty \\ &= 0 \quad \text{elsewhere} \end{aligned} \tag{7}$$

$$0 \le h(X,\alpha,\beta), \tag{8}$$

$$\int_0^\infty h(X,\alpha,\beta)dx = 1 \tag{9}$$

$$0 < g(X, \alpha,\beta) < \infty, \tag{10}$$

$$a(\alpha,\beta) < 1/g(X, \alpha,\beta), \tag{11}$$

$$1/c(\alpha,\beta) = a(\alpha,\beta)\int_0^\infty g(X,\alpha,\beta)\ h(\alpha,\beta)\ dx \tag{12}$$

The method proposed by Fishman is computationally easier and proves faster as implemented on the IBM 360/75. The steps for Fishman's algorithm are:

1) draw an exponential variable X with unit mean

2) draw a U(0,1) number,

3) if U(0,1) <= (X/exp(X+1)) α-1 then multiply X by α, then keeping this product as a gamma random variable other wise return to step 1. (Fishman:408).

Although the two methods may seem fundamentally different, they differ only in the choice of the majorizing function $h(X,\alpha,B)$, which does not even clearly appear in Fishman's method. Both these methods employ the rejection technique outlined in the general techniques section.

Another similar method is proposed by Tadikamalla, and compares favorably with Fishman for small values of α and is considerable better for larger values of α. This method uses the generation of Laplace variates (Tadikamalla:925-928).

Since many random beta variates will be generated in the course of modeling life cycle costs, efficiency and speed is very important. Kronmal and Peterson propose a modified Rejection method with Acceptance-Complement methodology that avoids repeating steps and has useful design flexibilities (Kronmal:271-281).

Greenberg has implemented a new density function able to approximate the type of data generally modeled by the non-integral gamma distribution through the mixture of integral gamma deviates which are much more quickly calculated (Greenberg:32-33). The method is quite simple and fast, but is not a true gamma, and using a ratio to generate beta variable is not recommended by Greenberg; however, it is possible that this density function could be used to directly model the data used to estimate costs, rather than to mimic a beta distribution.

Along the same lines , Ramberg, Dudewicz, Tadikamalla, and Mykytka have proposed a Generalized Lambda Distribution (GLD) that can take on the shape of virtually any of the commonly used distributions (Ramberg:210-214). Once again, the beta cannot be simulated directly but the authors have confidence in betas generated via ratios of gamma approximations. Although this would be slower than using one of the more direct gamma generators, the power of the GLD lies in its uses for exploring sensitivity analysis. Since the distribution can be shaped virtually any way, it can be tweaked to test the sensitivity of a model to any certain input distribution assumption. Indeed such a study was undertaken by the authors (Ramberg:210-214).

Also mentioned in the general techniques section was the use of the hazard function. Recall that the hazard function is the ratio of CDF to PDF and is unit exponential, and known density structure. A proof is offered by Devroye (Devroye:281). Devroye offers as many hazard rate based generation methods as have been noted already in this section, but applications to the beta distribution do not seem to be available in the literature.

III. Methodology

Model Definition

The first step in identifying the proper model is to research the models available. Of the various types of LCC modeling found in the literature, the methodology that is most appropriate for preliminary analysis is the parametric CER method, or cost factor model.

The cost factor model uses CER's and single variables as cost components to define the total cost of the system. For example, for some aircraft the radio cost may be represented by one single variable, the navigation system by a CER, and the engines by more CER's. Each of these cost factors also has some specific time frame (R&D costs are up front whereas operating costs occur later in system life).

<u>CER'S</u> - Recall that a CER is a cost estimating relationship (a regression equation). For example, the cost of a radio may be estimated by three dollars per channel it receives, twelve dollars per watt of transmitting power, plus fifty dollars for the basic chassis:

$$C = \beta_0 + \beta_1 X_1 + \beta_2 X_2 \quad (13)$$

where

C = radio cost
β_0= $50.00
β_1= $3.00
β_2= $12.00
X_1= channels
X_2= watts transmitting power

CER's attempt to estimate costs for future products based on characteristics shared with past products. The future products must have characteristics in common with the past products, to allow forecasting according to regression equations (based on those characteristics). Forecasting the cost of new technologies must be performed with great care. Obviously the cost of the B-2 engines cannot be estimated by comparison with the engines from the F-84, because the two do not share many characteristics.

The characteristics are the explanatory variables for the CER's, or regression equations. The distributions and parameters of each input variable must be specified. Additionally the β parameter estimates and their covariances must be known, along with the MSE of the regression.

Three basic types of CER's will be available in the model; natural logarithm, learning curve, and linear (regular) with explanatory variable power transformations allowed (Box:531). The overall system cost may be composed of up to twenty CER's, with each CER allowed up to ten components, or explanatory variables.

SINGLE VARIABLES - Some costs can be adequately represented by a single variable from one of the eleven available distributions. For example, the cost of a tire may be normally distributed by N(150,12) due to fluctuations in availability. Again the distribution and parameters for each variable must be specified when the system is defined. A limit of twenty single variable cost components imposed.

MONTE CARLO METHODOLOGY

The cost simulation methodology will be to predict the cost associated with each CER cost component and each single variable cost component (through random number generation), summing all these up to get one overall estimate of system cost:

$$\text{TOTAL COST ESTIMATE}_{I} = \sum_{j=1}^{n} \text{CER}_{j} + \sum_{k=1}^{m} \text{single variable} \quad (14)$$

where

n = number of CER's
m = number of single variable cost components.

By viewing many repetitions of this estimate the analyst may get an idea of the true cost distribution underlying these sample costs.

CER'S - Predicting the cost associated with one CER can be a very complicated task. The following steps capture the essence of the process. These steps are detailed more thoroughly in Chapter IV.

1) draw a set of dependent β parameters from a multivariate normal distribution according to the β covariance matrix.

2) sample each explanatory variable from the proper distribution.

3) transform each variable by the appropriate power.

4) multiply each transformed variable by the appropriate β value.

5) sum the products.

6) add a normally distributed N(0,MSE) value to the sum.

7) distribute the value of the sum according to the time phase specifications, then find the present values.

SINGLE VARIABLES - Single variable cost components are much simpler to simulate. Each variable is sampled from the appropriate distribution, time phased, and converted to a present value.

TIME PHASED SPENDING

After each cost component has been estimated (CER's and single variable cost components), it must be adjusted to a Present Value (PV) before it is added to the overall system cost. Obviously money spent during different phases will have different PV's due to the discount rate (interest).

For example: Farmer Brown owes $100.00 to the Farm Equipment Corporation and $100.00 to the General Feed Store.

However, the equipment bill is not due until next year. If the current interest rate at the local bank is 10%, Farmer Brown may invest \$90.91 and allow the money to collect interest, or "grow" to \$100.00 over the next year:

$$PV(\$100.00) = 100/(1 + r)^{N} = \$90.91 \tag{15}$$

where

r = periodic interest rate, 10% here
N = number of periods into the future, 1 here

The feed bill however, must be paid now, costing Farmer Brown the entire \$100.00. This is the concept behind present values; "How much will I have to invest now to have \$XXX.XX at some point in the future?" Obviously this depends on how far into the future the money is due and the prevailing interest (or discount) rate.

This creates a need for the user to specify the timing of the money to be spent and the current interest rate. The spending process is broken into four periods, called the NOCOST period, Phase In period (PI), Constant period (CON), and Phase Out period (PO). The user must specify the length of each of the time periods (which may be zero) for each cost component.

Figure 5 shows examples of various time phase configurations. The total area associated with each year (ie. under the curve between 0 and 1 for the first year) will determine how much of the money from the cost component

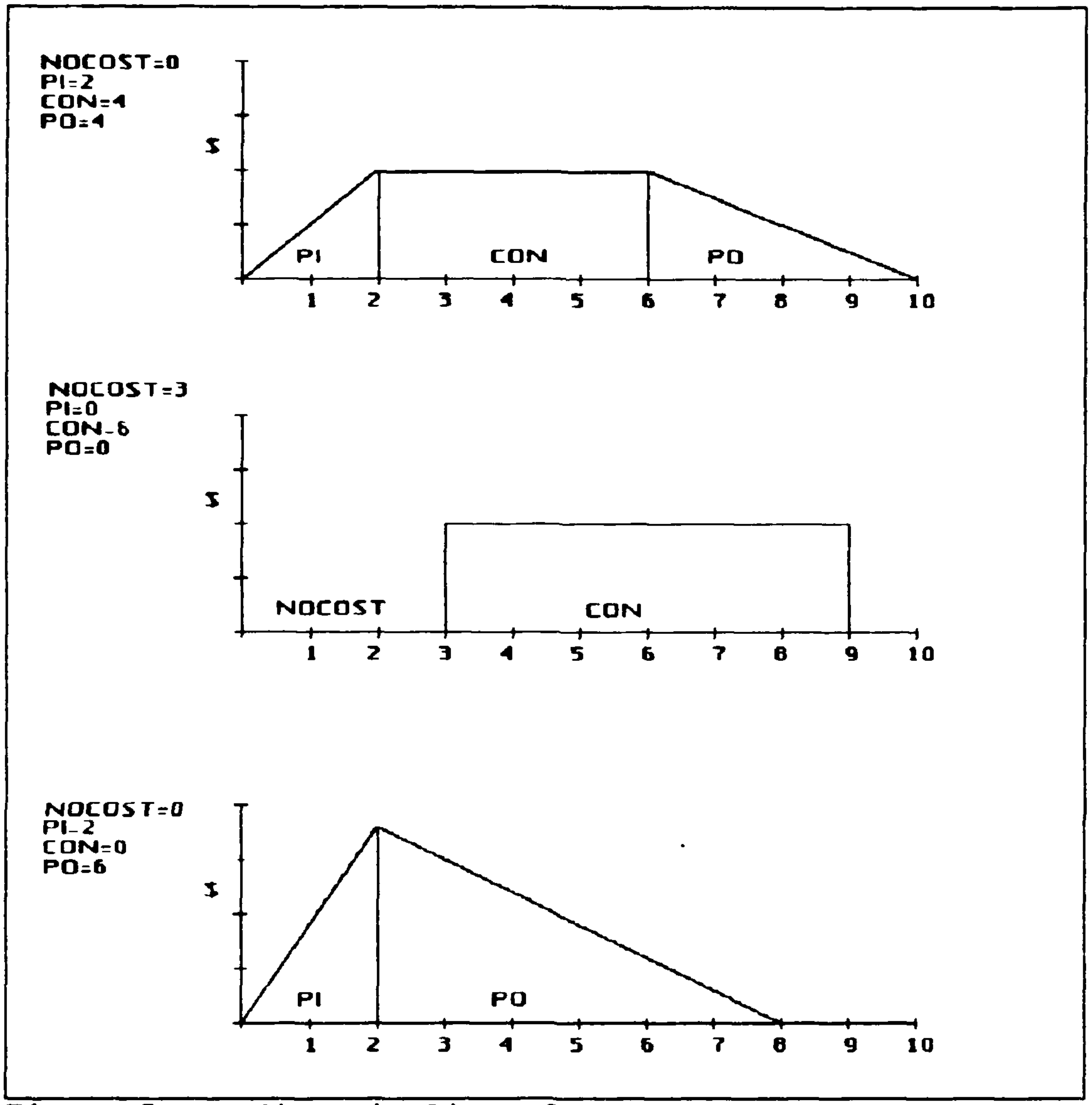


Figure 5 Spending timelines for cost components.

in question will be spent that year. Note that the second spending timeline has no NOCOST, PI, or PO period, and the last has only PI and PO periods. Remember that each separate cost component has its own timeline, and that the sum of these timelines would give an overall $/year timeline for the system.

Although this method does not nail down the exact amount of money to be spent each year, it requires only four time parameters from the user, and it will suffice for preliminary cost analysis.

OUTPUT ANALYSIS

Now that a set of cost estimates for the system in question has been produced, through Monte Carlo simulation, the set must be examined. It is wise to gather as much information as possible about the simulation and its output since the experiment cannot be run with the real world system. The object of this section is to guide the user through descriptive tests and procedures designed to explore the underlying distribution of possible costs for the system in question.

FREQUENCY HISTOGRAM - A frequency histogram is a graphical representation of the number of data points that fall into each of a set of numerical ranges, or classes. Viewing a histogram can lend insight to how the population underlying the data sample is distributed. Figure 6 is an example of a histogram (produced by the Frequency Histogram option of this software and converted to black and white). This figure shows the number of data points that fall into each of the numerical classes. The upper class bounds are written at the bottom of the graph under the boundaries of the bars. The X axis is in the units of the data set. The

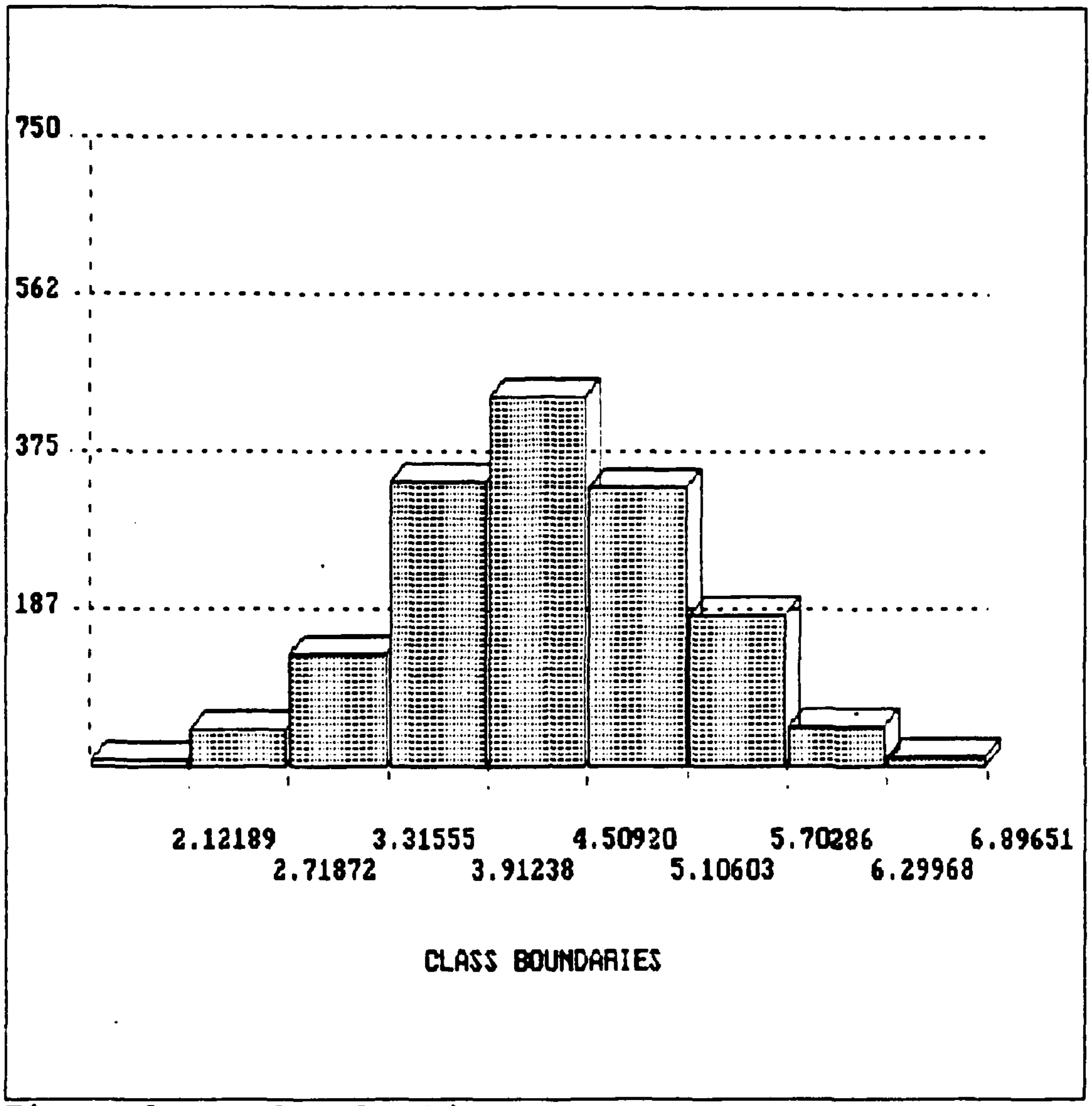


Figure 6 Example of a histogram.

Y axis is the frequency of observations.

<u>MOMENTS</u> - The first two moments of a sample, the mean and variance, give some idea of the data range and spread. This information can facilitate comparisons among data sets. Also useful are the extreme high and low values, the standard error of the variance estimator, and the median, or

the fiftieth percentile of the data (see the next heading for more percentile information).

QUANTILE ESTIMATION - Quantiles, or percentiles, deal with the order, or rank, of data points. The fiftieth percentile is the middle point of the data after the set has been sorted (ie. of 3, 4, and 5, 4 is the fiftieth percentile). The fiftieth percentile is also called the median. Unless the data of interest is normally or uniformly distributed, the median is often more useful than the mean in describing the typical value of the data points.

The value of any quantile, from anywhere above 0 to anywhere below 100, can be estimated. Thus at the ninetieth percentile value, X, there is a ninety percent chance that subsequent random values (from the same distribution) will be lower than X. Another way to state this is that ninety percent of the values drawn from this distribution will be less than X.

NON-PARAMETRIC PROBABILITY - At times it would be very useful to know the probability of drawing a number smaller than some reference value from a give population. This is a very simple problem should you know the true distribution of the population and its parameters (mean, variance, high, low, α, β etc.). However, the analyst will rarely know the distribution type of the simulation output data. Rather than performing some lengthy set of weak tests to ascertain which distribution is at hand, it is possible to use nonparametric order statistics to estimate the probability introduced above.

The problem of finding a probability associated with some value, is the opposite of quantile estimation, finding the value associated with some level of probability. Both quantiles and probabilities are yet another way to conduct comparisons among the cost distribution of competing systems.

Note that the descriptive methods described so far are **non-parametric, meaning they do not require any assumptions about the distribution underlying the sample data.**

T-TESTS FOR SAMPLE MEANS - Through T-tests the analyst may test the hypothesis that the means of two systems' cost distributions are the same. These tests are very important because point estimates of means, as well as other parameters, can be very misleading. The fact that the mean of one sample is higher that the mean of a sample drawn from a different distribution, is not enough information to conclude that the underlying distribution means share the same relationship.

T-TEST 1 - This T-test is for two independent populations with the same variance (σ^2). Although the variance need not be known, the hypothesis of $\sigma_1^2 = \sigma_2^2$ must be tested (with failure to reject) before this T-test can be used. This T-test assumes normally distributed samples are used, which is a good assumption for large samples since X approches normality as the sample size approaches infinity.

<u>T-TEST 2</u> - This T-test is for two populations with the unequal variances (σ^2). The variances need not be known, and need not be tested for equality. However, this test should not be used unless the test above is invalid due to differing variances. The test above is a much stronger test, meaning it will be able to reject the null hypothesis ($\mu_1 = \mu_2$) more often, without more error. This T-test assumes normally distributed samples and independent populations, like the test above.

<u>T-TEST 3</u> - **This test is for paired data. It is not appropriate for analyzing the output from this Monte Carlo simulation**, but it is offered for use with other simulations or observations. The populations in question should be dependent. Elements within pairs of observations can and should be correlated, being observed from similar scenarios. For a more complete discussion of paired data see Johnson (374) or any other elementary statistics text.

<u>NON-PARAMETRIC TESTING</u> - The following section will outline how to perform tests similar to the T-tests above, but without making assumptions about the underlying distributions. Additionally these tests will allow hypothesis testing for any quantile, or probability, for any two distributions.

TEST FOR EQUAL QUANTILES - Quantile estimation can be used to test the hypothesis that the N^{th} quantiles of two distributions are equal, provided confidence intervals (CI's) have been also estimated. Simply stated, if the CI for the N^{th} quantile of sample set A intersects with the CI for the N^{th} quantile of sample set B, then fail to reject the null hypothesis. Should the two CI's not intersect, reject the null hypothesis.

It should be noted that such joint use of the two confidence intervals (each encompassing α amount of risk) compounds the risk associated with the α values used to create the confidence intervals.

For example, if the two confidence intervals are created with $\alpha = 0.1$ (as in the program) then the total confidence in the outcome of the test is a product of the separate confidences:

$$C = \prod_{i=1}^{N} (1 - \alpha_i) \tag{16}$$

or

$$C = (1 - \alpha_1) * (1 - \alpha_2) = 0.81 \tag{17}$$

providing the separate confidence intervals are independent (they are when produced by this Monte Carlo simulation program). If the two intervals were not independent (ie.

produced from the same run of some other simulation program) the α's are added to get the overall amount of risk associated with the test:

$$C \geq 1 - \sum_{i=1}^{N} \alpha_i \tag{18}$$

or

$$C \geq 1 - (\alpha_1 + \alpha_2) = 0.8 \tag{19}$$

would describe the confidence in the test above, if the confidence intervals were not independent. This is known as the Bonferroni inequality (Kleijnen:41). The actual confidence is greater than or equal to the resulting confidence factor, thus the name evolved.

IV. IMPLEMENTATION

RANDOM VARIABLES

The heart of a Monte Carlo simulation is the set of random number generators, and the heart of all the random number generators is the uniform(0,1) generator used to feed them. This U(0,1) generator was taken from Numerical Recipes: The Art of Scientific Computing (Press:199). This generator was tested for mean, variance, and serial correlation (see Appendix B). There were no apparent problems.

Although it is possible to speed up the random number generators by programming them in assembly language, this hampers flexibility in support of the code. So assembly language was not used. All the univariate distributions below are available for single variable cost components as well as CER input variables.

BETA SAMPLING - The nine beta distributions shown in Figure 7, taken from Dienemann, provide a wide range of characteristics. The beta deviates are generated using the ratio of gammas discussed in Chapter II, Eq(3). The gamma variables used for the ratios are generated using either Fishman's or Wallace's method (one is much faster for $\alpha \le 1.0$). Both are discussed in Chapter II. The beta

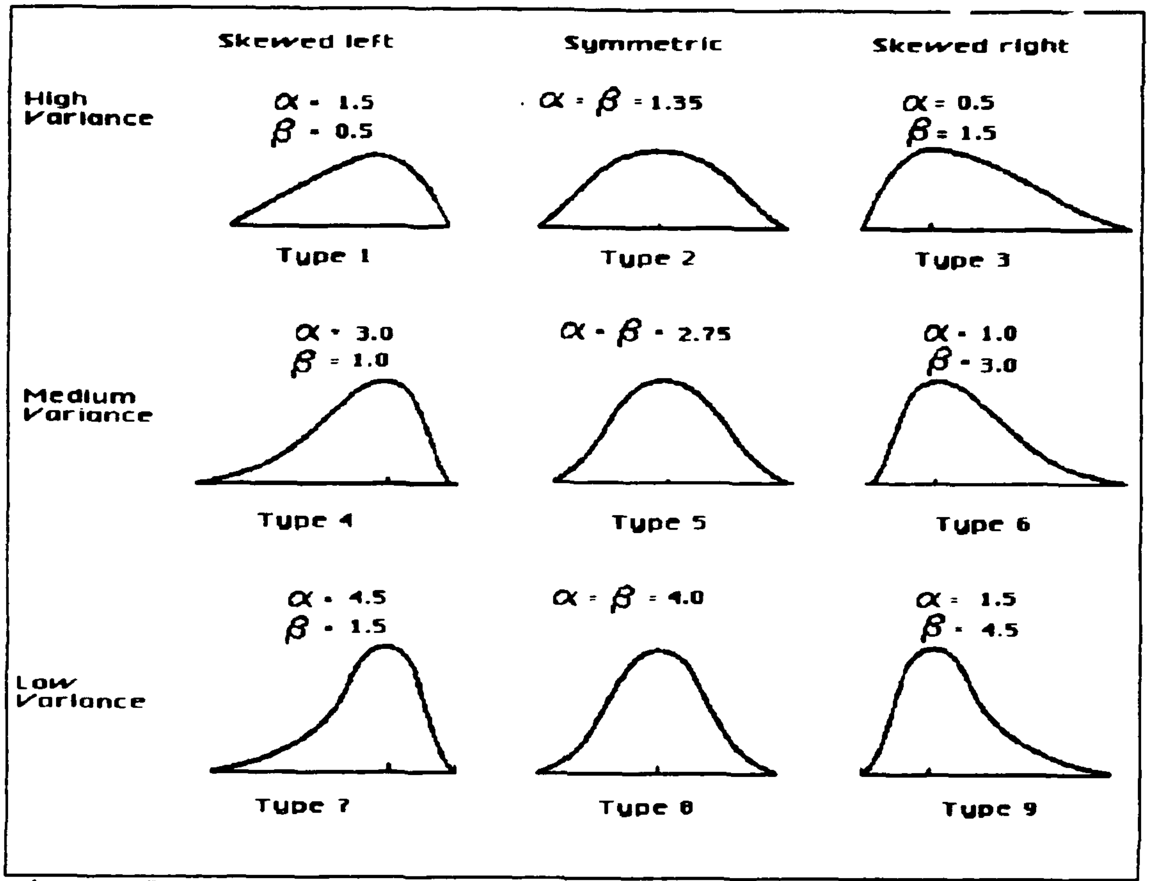


Figure 7 Input uncertainty probability distributions (Dienemann:14).

deviate is generated on the (0,1) interval and multiplied by (hi-low) and then added to the low value specified by the user:

$$\text{Beta}(\alpha,\beta)_{(hi,low)} = \text{Beta}(\alpha,\beta)_{(0,1)} * (\text{hi-low}) + \text{low} \qquad (20)$$

<u>NORMAL SAMPLING</u> - In addition, the normal distribution is also available for CER explanatory variables and single variable cost components. The analyst should exercise caution when specifying a cost as a normally distributed deviate since normally distributed variables can easily have negative values (which make no sense in terms of cost and cannot be used in power transformations). The normal deviate is calculate by the following equation (Ross:447):

$$N(0,1) = (-2 \ln(U_1(0,1)))^{1/2} * \cos(2\pi\, U_2(0,1)) \qquad (21)$$

This produces a standard normal deviate. To achieve a deviate from the proper distribution, the value must be multiplied by the standard deviation and added to the mean:

$$N(\mu,\sigma^2) = N(0,1) * (\sigma) + \mu \qquad (22)$$

UNIFORM SAMPLING - [The easiest of them all.] A uniform sample is create by multiplying the U(0,1) deviate by the (hi-low) and adding it to the low:

$$U(low,hi) = U(0,1) * (hi-low) + low \qquad (23)$$

MULTIVARIATE NORMAL SAMPLING - This is the most direct and technically pleasing way to account for the variance of the β parameters of the CER's. The β's must be distributed according to their means and the covariance matrix, $\beta_{est.} \sim (\beta,(X'X)^{-1}\sigma^2)$. The following set of steps captures the essence of the process:

1) reduce the covariance matrix to its Cholesky square root (Maindonald:17)

2) draw a vector of independent, standard normal deviates

3) multiply the vector by the Cholesky matrix

4) add the estimated means to the remaining vector of deviates.

or

$$\beta_{sample} = \underline{C} * \underline{N} + \beta_{HAT} \tag{24}$$

where

$\underline{C}$ = Cholesky square root of covariance matrix
$\underline{N}$ = vector of independent standard normal deviates
β_{HAT} = estimated means
β_{sample} = one sampled vector of dependent normals

This is the same type of algorithm used by the IMSL library routine.

COST ESTIMATION

Each CER is evaluated according to its type. Linear CER's are the simplest (described in Chapter III). The natural logarithm CER's are handled much like the linear CER's with two exceptions:

1) after each explanatory variable is sampled, its natural log is taken

2) after the rolling sum for that CER is totalled its exponent is taken (inverse natural log, ie. e^{Total}).

Let it be clear that the X variable must be specified in its actual form for Ln CER's; the program will take the Ln of the explanatory variables during the calculations. The output variable is return in its standard form as well, the exponentiation is taken care of by the program.

For example, suppose

$$Y = X_1^{\beta 1} \quad X_2^{\beta 2} \tag{24}$$

and the X variables are uniformly distributed between 5 and 10. The β parameters are estimated by:

$$Ln(y) = \beta 1 \; Ln(X_1) \quad + \quad \beta 2 \; Ln(X_2). \tag{25}$$

with linear regression software. For the purposes of this program, X_1 and X_2 should be described as uniform with low=5 and hi=10. The program will handle the natural logarithms and output Y (not Ln[y]).

The learning curve CER adds one more twist. It too is a natural log process, but after the final CER value (e^{Total}) is calculated, it is multiplied by X_1, the first explanatory variable. This is because learning curve CER's apply to individual parts, needing to be multiplied by the total number of parts purchased (X_1) to find the total cost for that component. Like the Ln CER's, the variables for the learning curve CER's should be specified in standard form (non-log).

POWER TRANSFORMATIONS

Power transformations on the input variables can lend extra explanatory power to linear equations. In essence, these transformations allow nonlinear fitting with linear software and methodology.

The process for finding the optimal power transformations (Box:) has been implemented along with a basic regression tool in the limited version of MATRIX (also written by the author). This implementation of the Box algorithm accepts up to 39 input variables and up to 80 observations, which is usually adequate in light of the small data sets used to produce CER's. It should be noted that power transformations can only be estimated by using the original data. The user must first estimate the power transformation, then transform the data and generate his own new CER.

Note: MATRIX cannot take a power transformation on a variable with a negative value. Ensure that no power transformation is specified for any variable that can possibly be negative. Be especially wary of normally distributed variables.

Use of this program will provide the user with the optimal power transformation value (α) for each explanatory variable (one CER at a time). Since this is accomplished through successive regressions, the original data used to generate the CER must also be used to find the correct transformation.

For example, if the fixed part of the model is actually:

$$Y = X_1^{4} + X_2^{1/3} \tag{26}$$

the algorithm will return α values of 4.0 and 0.33 (or very near there) for X_1 and X_2 respectively when given the X matrix and Y vector. The analyst must then make the transformations to the X data and estimate a new CER (MATRIX can do both). The α values and the new β values (along with covariances and MSE) that are estimated using the MATRIX program are then entered during the CER definition phase of the model builder program.

Box and Draper (Box:296) offer a lengthy discussion on process of estimating power transormations which boils down to the following steps:

1) fit a the model $Y_u = \sum_i \beta_i X_i + \text{error}_u$
2) form $Z_{iu} = \beta_i * X_{iu} * \text{Ln}(X_{iu})$
3) fit a model with the Z's as new input variables, $Y_u = \sum_i \beta_i X_i + A_i Z_i + \text{error}_u$
4) for A_i that are significant (using t-test), set $\alpha_i = A_i + 1$

5) raise X_i to the α_i power for all α_i that are significant, across all observations.

6) repeat steps 1-5 until no Z's are significant, keeping track of the cumulative effect of each α.

TIME PHASED SPENDING

Remember that each CER of single variable cost component has its own spending timeline defined by NOCOST, PI, CON, and PO. Figure 5 shows the spending time line for a CER. The total length of this spending process is seven years (total of NOCOST, PI, CON, and PO). This means that the money associated with the CER (the output variable) will be spent in seven lump sums, one payment at the end of each year (the model assumes spending at the end of each period).

NOTE: The actual spending profile should be based upon the likely pattern of payments to the constractor (progress payments are often embodied in the contract). This may or may not correspond to the expected delivery date(s) of the hardware.

The goal is to find how much of the money is spent each year, as specified by the four time period values. The sum to be paid at the end of each year is proportional to the amount of area under the curve in the block for that year. In Figure 8, the area of C, associated with year 1, is just over 3% of the total area:

$$\text{proportion} = C / (A + B) = 0.1666 / 5.5 = .03 \qquad (27)$$

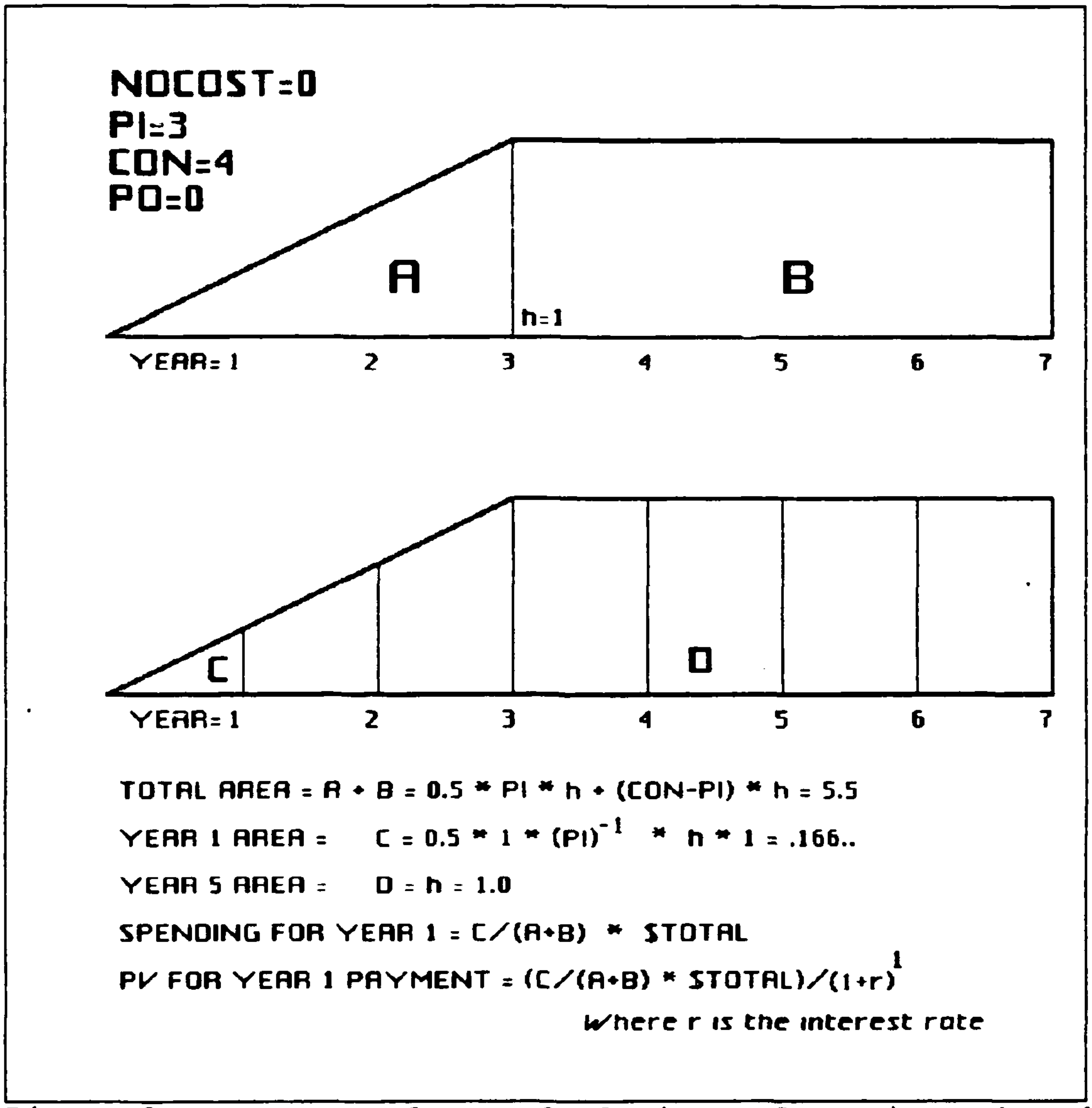


Figure 8 Present value calculations for time phased spending.

That means that just over 3% of the total cost associated with this CER will be incurred at the end of the first year. The sum due at the end of each year is calculated in the same basic geometric fashion.

Once the total cost associated with one cost element has been broken down into yearly expenditures, each expenditure must be adjusted to a present value. The adjustment is made with Eq (13) from Chapter III. The sum of all these present values:

$$\text{Component cost} = \Sigma_{i=1}^{N} PV_i \tag{28}$$

where

N = nocost+pi+con+po (years over which to spend money)

is the final cost associated with this one cost element (CER in this case). The total system cost (life cycle cost) will be the sum of the present values of all the cost components:

$$\text{TOTAL COST} = \Sigma_{J=1}^{M} PV\,(VAR_J) + \Sigma_{P=1}^{K} PV\,(CER_P) \tag{29}$$

WHERE

M = number of variable cost components
K = number of CER's

Software Production

The routines have been be consolidated into a single program with a homogenous control structure. The user interface is a system of pop-up menus and windows with cursor selection for novice users, as well as first letter selection to facilitate "command language" use by experienced users.

Documentation

The User's Manual (Appendix A) will provide every bit of information needed to operate this software. The function of each menu item is discussed, and a one example tutorial is provided.

Appendix C provides all the source code for the Monte Carlo simulation program and the MATRIX program. Inline comments and the readable style of Pascal code make it quite understandable.

V. CONCLUSIONS AND RECOMMENDATIONS

THE GOAL

The goal of this effort was to develop a tool to enable quick preliminary analysis and comparison of weapon system costs. That goal was realized. The PC environment is quite adequate for the simulation of LCC costs. Parametric LCC estimation is both quick and easy.

VALIDATION/VERIFICATION

Verification was performed on each procedure and the system as a whole. Remember that verification is checking to see if the code performs as intended. Validation, on the other hand, is checking to see that the methodology that has been implemented in the code actually model the real world closely enough.

Validation is difficult because this software is a model building tool. The user builds his own model of the real world with the CER's and single variable cost components he uses to describe the costs.

This program will accurately and consistently produce forecasts of the costs, as they are described by the user. Whether or not the user's model accurately captures the essence of his part of reality is beyond the control of the author. Bottom line: the user must validate his own model.

RECOMMENDATIONS FOR FUTURE RESEARCH

VARIANCE REDUCTION - Each output parameter generated by any simulation is an estimate. It is only natural to want the best possible estimate of each parameter. Variance reduction offers the possibility of increasing the power of this simulation software. Whether or not the common techniques of variance reduction can tighten the confidence intervals generated by this software without biasing the estimates of the output distribution's spread is not clear to the author. Due to time constraints sufficient research and experimentation was not performed in this area.

Since all source code has been documented and provided herein, the software should not cease to develop. In particular, the use of variance reduction could be studied through experimentation. Several runs of a model using various types of variance reduction, and none, could provide adequate data for an analysis of variance describing the effect of the different variance reduction techniques.

PARAMETRIC LCC ESTIMATION VALIDATION - Now that a powerful and easy to use tool has been provided, the validation of parametric cost modeling can be undertaken much more swiftly. Essentially, a follow-on to researcher could probe that actual value of the modeling methodology without having to sweat the details of implementation.

RANDOM DEVIATE GENERATION - It has been suggested that triangular distributions can be used in place of beta distributions with little loss in accuracy. If this is the case, then a great deal of time may be saved by replacing the acceptance/rejection generators used for beta deviates.

APPENDIX A: INTERACTIVE LIFE CYCLE COST FORECASTING TOOL

USERS' MANUAL

APPENDIX OVERVIEW

The purpose of this users' guide is to assist with the actual keyboard entries necessary to use the software. The three sections of this manual do no contain sufficient information to use the software properly. Theory, methodology, and assumptions should be reviewed in the preceding chapters before the software is used.

The fist section deals with the user environment; the menu system and the entry conventions required by the language. The second section is a listing and description of the functions available. Provided in the third section is a numerical example with a keystroke by keystroke tutorial.

THE USER ENVIRONMENT

RESPONDING TO PROMPTS - There are certain conventions that must be observed when using this software, most of them deal with data entry. Following is a list of the most commonly violated conventions.

REAL NUMBERS - real numbers (eg. 2321.234 or 0.345) must be entered with at least one digit left of the decimal and no commas. Reals less than one may not be entered without a leading 0. For example, .5 is not allowed, nor are fractions such as 1/2; 0.5 is the only way to enter the value. The value 10,567 may only be entered as 10567 or 10567.00 or 1.0567E4. -0.03329 can only be entered as such or as -3.329E-2. Notice that scientific notation is allowed, as used in the preceding examples.

INTEGERS - integers must be entered much like reals except that decimals and digits left of them are not allowed. Like with reals, commas are not allowed. For integers scientific notation is not allowed.

FILE NAMES - When the user is prompted for a filename, a string of up to eight characters may be used. These characters may be letters, numbers or symbols. No extension is required or allowed. Extensions are assigned automatically depending on the file type. Data set files are give .SET and the LCC system files are given the .STM extension. Following each file name prompt will be a default name. To accept the default name simply press CR.

EXCEPTIONS - The above rule concerning file extensions does not apply when the user is prompted for the file to **read** in the **READ ASCII** option. Nor does it apply when the user is prompted for the filename to **write** in the **WRITE ASCII** option. These filenames should be given the appropriate extensions since they apply to ASCII files, not data set file used by this software. The data set files will still retain their .SET extensions.

THE SCREEN PRINTING PROMPT - In some of the routines, the user has the option of getting a printout of the graphics that will appear on the screen (FREQUENCY HISTOGRAM, TIME SERIES PLOT, MOMENTS, XY PLOTS). Simply answering yes to the prompt will not ensure that a hardcopy of the screen will be produced. This option works only if a screen dump utility has been installed.

With some systems the DOS command GRAPHICS is sufficient (this DOS feature does not seem to work for all computer-monitor-printer combinations). Some printer manufacturers provide custom screen dump routines for their printers. Another possibility is using a public domain dump utility such as EGADMP that is provided with the CHART package.

Once one of these utilities has been installed, graphics may be printed by requesting a dump from the routine, or simply pressing SHIFT and PRTSCR simultaneously while the graphics are on the screen. The same action will dump a text screen to the printer. If lines and boxes do not appear on the hard copy as they do on the text screen, exit the program and issue the DOS command GRAFTABL. This enables DOS to send the extended ASCII characters that define lines and corners to the printer. Some printers require that the IBM mode be activated to print these symbols. Check your printer manual.

MENU OPERATION - This sub-section deals with the specific operation of the menus. This is a custom, pop-up menu system written by the author in Turbo Pascal 4.0. Figure 9 is a black and white reproduction of the main menu. This menu offers six choices; the data menu, the statistics menu, the T-testing menu, the Files menu, the Random deviates menu, and setting a new seed for the random number generators.

A menu choice is selected by pressing the key corresponding to the first letter of the choice. Note that all the first letters are in bold type to remind you of this selection method. To select the statistics menu press the S key.

Another way to select a menu item is to use the arrow keys to highlight the desired item and press the carriage return (or enter) key. Notice that the Data choice is underlined in Figure 9. This indicates that this item would be highlighted in a different color on the computer screen. Pushing the down arrow once would cause the Data item to return to normal colors and the Statistics item to become highlighted. This is much easier to see with the software actually running on the color screen.

If a mouse is installed with cursor key emulation, the mouse may be used rather than the cursor keys. One of the mouse buttons must emulate the carriage return key for actually selecting one of the menu items. A mouse driver is provided with the package (for the Genius family of serial mice).

The QUIT option on the main menu is replace by a BACKUP option on each subordinate menu. The BACKUP option takes you back up one level to the previous menu. For example, selecting the BACKUP choice from the data menu will make the program exit the data menu and return to the main menu.

GENERIC MODEL BUILDER -- by Dave Sumner

MAIN MENU

Data
Statistics
T-testing
Files
New seed
Random deviates

Quit

Figure 9

MENU LAYOUT - Figure 10 shows the layout of the menus. This will make it easier to find a function without roaming through the entire menu system. Unlike some commercial packages that claim to enable their users (pun intended), these routines are laid out in logical groupings.

Some menu choices call another menu, while others perform functions. The thick boxes with capital captions in Figure 10 represent menus while the thin boxes with lower case captions are procedures. For example, the DEFINE option on the DATA menu is actually a subordinate menu offering several choices, while the ENTER option is simply a keyboard data entry procedure.

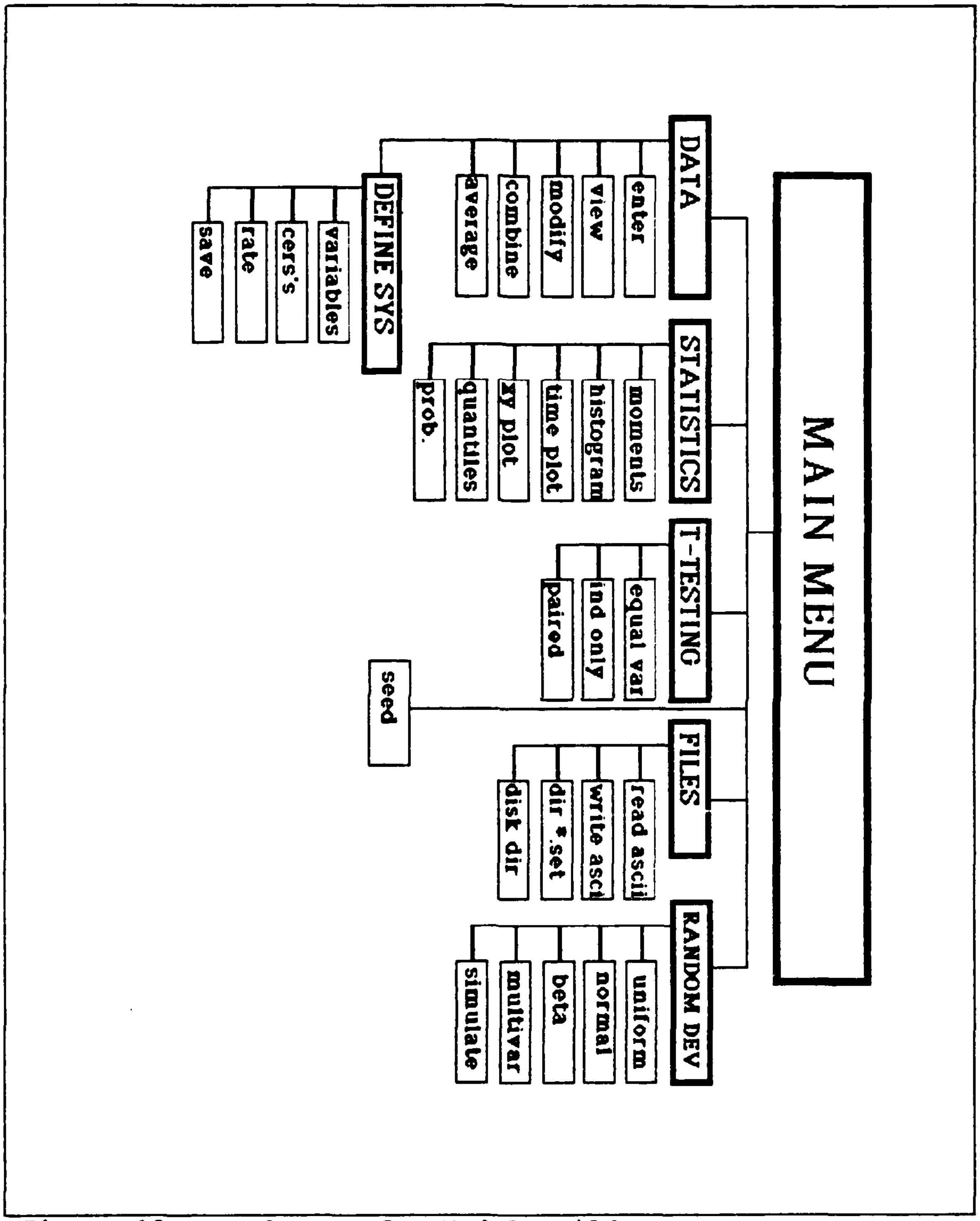


Figure 10 Menu layout for Model Builder.

AVAILABLE FUNCTIONS

DATA MENU - The data menu handles the 'administrative' duties such as data entry, correction, combination, and viewing. One mathematical routine, averaging, is offered.

ENTER - Allows for data entry from the keyboard. Saves the data set to a .SET file for use with the statistical functions. See READ ASCII under the file menu. After selecting this item a work window will be opened and the user will be prompted for a file name under which to store the new data set. If the file name entered already appears on disk, the user will be notified and asked if he wishes to proceed (overwrite). Answering yes will not overwrite the file yet. Enter one data value at a time, pressing the carriage return (CR) after each value. After typing in all the values, enter a "q" at the next prompt. The user will get a chance to change the name of the new data set, or overwrite the old data set if a data set with the same name already exists.

VIEW - This option writes the data values to the screen. It will scroll without pausing if there are more values than space on the screen. The <control S> keystroke can be used to stop the scrolling, but a better idea is to write the data to an ASCII file (see FILE menu) and view it with your favorite editor.

MODIFY - Allows the user to change any data point in a set providing the user knows the number of the point that needs to be changed. Not very useful for large data sets. It is easier to write the data to an ASCII file, edit with your own editor, then read the ASCII file back in (see READ ASCII and WRITE ASCII at the FILE menu).

COMBINE - Prompts the user for two data set names. Reads the sets from disk, concatenates the second file onto the end of the first and saves the new data set to disk.

AVERAGE - The only mathematical routine on the DATA menu. Will prompt the user for a data set name. After reading the set from disk the routine will ask for another data set name. The values of the two sets will be averaged, ie. the mean of the first value of each set, then the mean of the second value from each set. The routine will continue to prompt the user until the user enters "q" to indicate that no more files should be averaged. This is useful for averaging the observations between simulations runs without averaging within the runs, for tasks such as beginning of steady state identification.

DEFINE SYSTEM - This item calls another menu, the LCC system definition menu. This is where cost simulation begins. Here a system is defined, with variables and CER's, so a Monte Carlo simulation can be run to forecast the cost distribution of the system in question.

VARIABLES - This item allows the user to define the single variable cost components. The user will be prompted for a filename. If the file already exists, the

"-- File read --" message will indicate that the user is updating a file that already exists. If the name is new and unique, the "-- New file --" message will indicate so. Now enter the number of single variable cost components for this system. For each variable enter the variable type, an integer from Figure 11, along with the appropriate parameters as they are prompted for. Be sure to know the NOCOST, PI, CON, and PO values before sitting down to define the variables.

<u>**CER'S**</u> - Prompts for information defining CER's. File name prompt and message are exactly like above. Enter the number of CER's, and the number of the CER to be defined now (each CER must be defined with a separate pass through this option). As the prompts suggest, enter all the information associated with the CER. First the number of input variables for the CER. Next define each variable and its power transformation. If no transformation is desired enter "1.0".

After the input variables are defined, enter the estimated β parameters. Next enter the covariances, paying careful attention to which covariance the routine is asking for (eg. cov[1,1]=var[β_1], cov[1,2]=cov[β_1 β_2]). All that remains is to enter the MSE from the regression used to determine the CER.

As noted above this routine must be called three times to define three CER's. It is a good idea to save the file

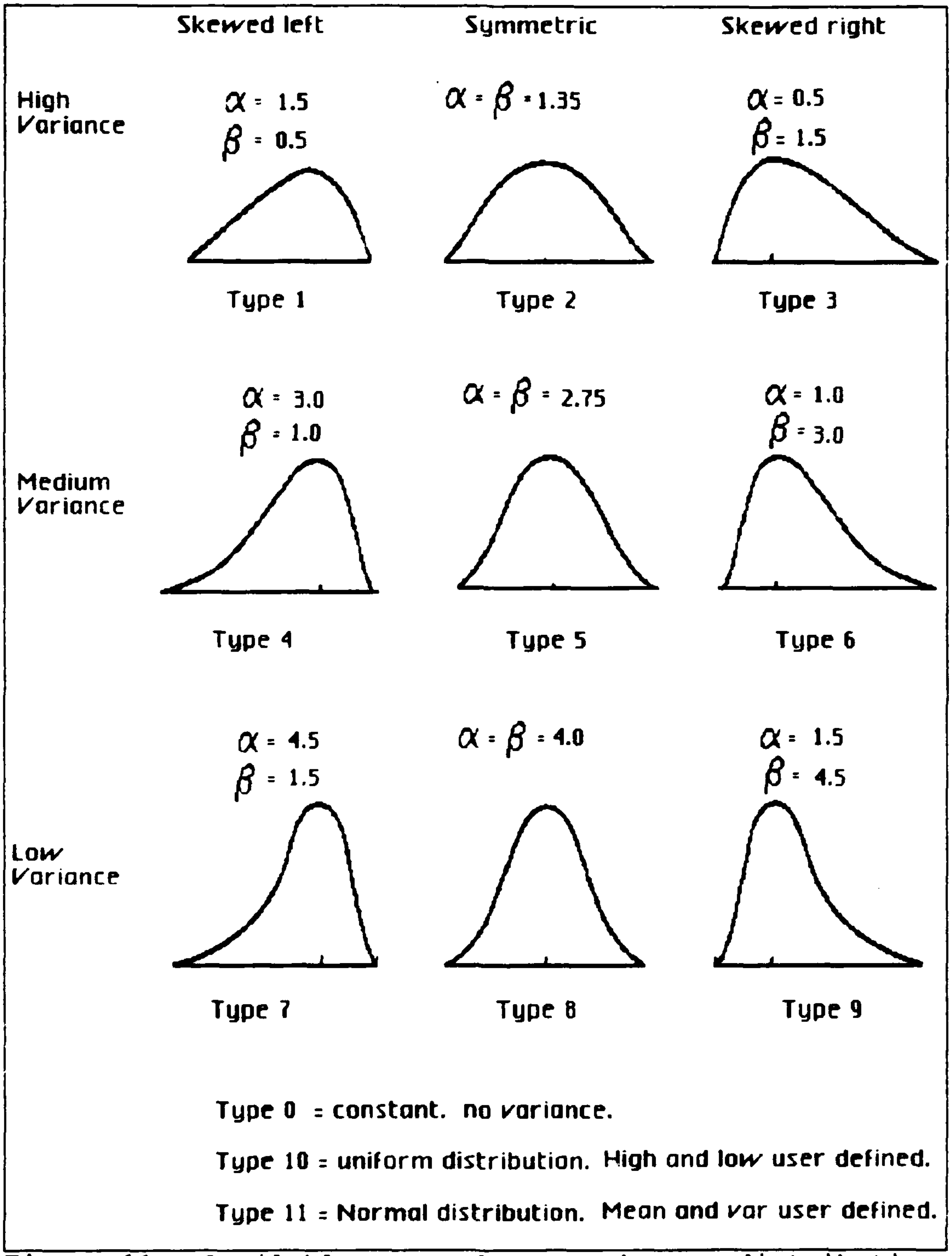


Figure 11 Available random number distributions (modified from Dienemann:14)

each time a CER is added, just in case.

<u>RATE</u> - Prompts the user for the interest rate to use for the present values. This interest rate should be entered as an Annual Percentage Rate (APR). For example if the current interest rate is 10% annually, enter 10.0. **<u>If no interest rate is desired enter 0.0. There must be a value for interest rate.</u>**

<u>SAVE</u> - Saves the information entered to a system definition file with a .STM extension for use with the Monte Carlo simulation module. It is prudent to save the system file between each phase of definition (variables, CER's, and interest rate).

<u>STATISTICS MENU</u> - This is the section of the program that does most of the actual work. Nearly all the numerical processing routines are handled here.

<u>MOMENTS</u> - Prompts user for a data set name. Calculates the mean, median, variance, standard deviation, low, hi, and number of data points for the set. Additionally a 1 axis plot of the data is created to facilitate identification of outliers, or clusters.

Figure 12 shows the display generated by this routine. The two tick marks near the center of the number line are the mean and the median (color coded with the words in the table no the actual screen). Note that the data points are lined up along a number line. Note also that if more than

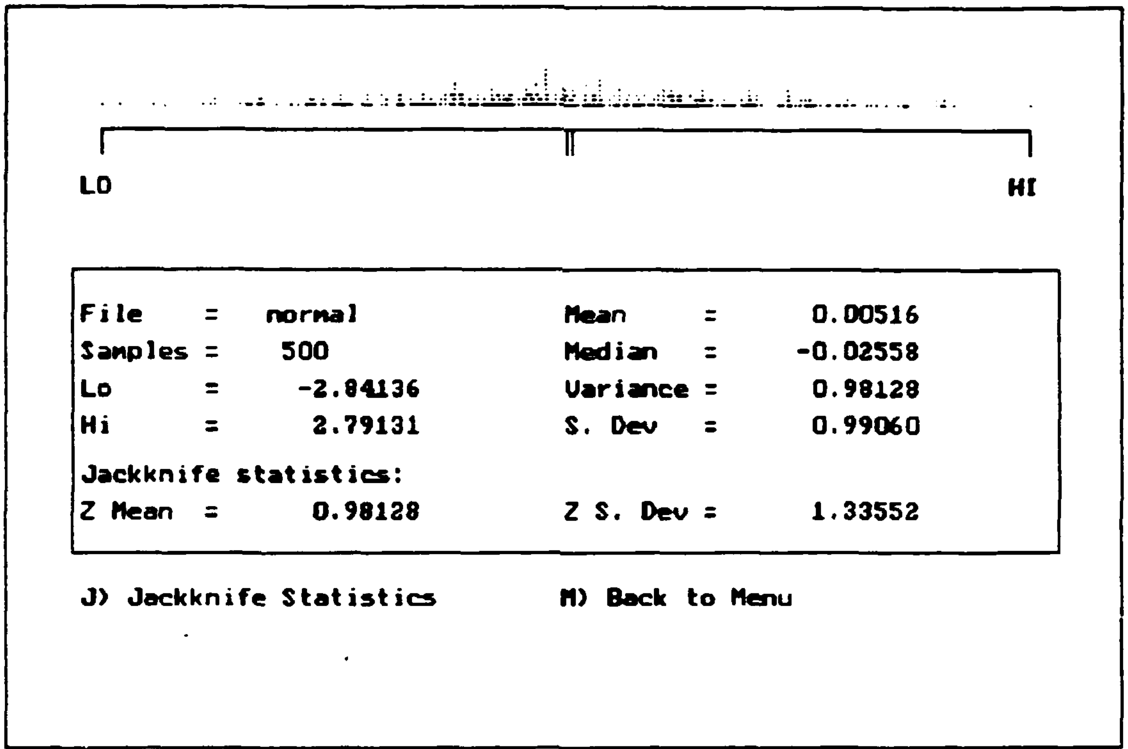


Figure 12 Example of MOMENTS output.

one data point has the same value, then all the data points (dots) are stack vertically at the position on the number line associated with that value. This can give the analyst some idea of the spread, or distribution of the data, but the frequency histogram is more suited for this purpose.

The jackknife statistics given are an unbiased estimate of the population variance (Z mean) and the standard error of that estimator (Z std dev). These figures are used to draw a symmetric confidence interval on the population variance, in the same way the sample mean and sample standard deviation are used to draw a CI for the population mean. The jackknife statistics are calculated only at the user's request (by selecting "J" while viewing the plot).

FREQUENCY HISTOGRAM - After prompting the user for a data set name, this routine will ask a series of questions. listed below are the options corresponding to the questions.

1) Printout - Answer by selecting "y" or "n". This forces a screen dump, making a hardcopy of the graph. See the conventions section for more information.

2) Number of classes - Answer by entering an integer between 5 and 20, inclusive. Sets the number of classes, or ranges, and the number of bars on the graph.

3) Automatic classing - Answer by selecting "y" or "n". If "y" is chosen the range of data will be separated into N equal width ranges, N being the chosen number of classes. Otherwise, the user will be prompted for the upper limit for each class. This is useful for viewing two distributions under the class structure.

Figure 13 offers a sample histogram with nine classes. The number of classes will vary with number of samples and type of data, but nine is usually a good starting place.

TIME PLOT - After prompting user for a data set name, this routine will offer the option of using a moving average. If the user enters "y", he will then be prompted for any odd integer, specifying the size of the moving average window. This will result in the plotting of the moving average points, rather than the actual data. This

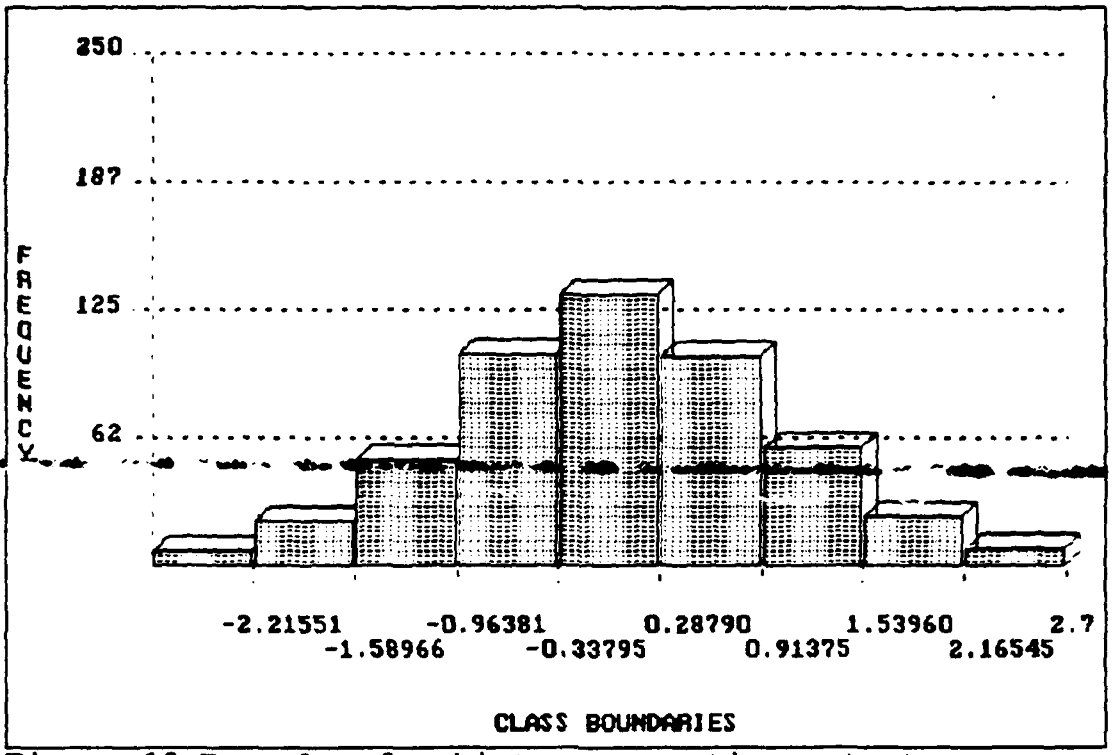


Figure 13 Example of a histogram routine output.

option is good for checking the data for serial correlation. This is not useful for the output of this model building program.

Figure 14 shows an example of a time series data plot. Note that the text displays the size of the moving average window (0 if moving average is not used). The line through the data represents the mean (color coded to the word mean and the number on the actual screen). Only the first 500 data points will be plotted.

XY PLOT - Provides an X vs Y plot of two data sets. The user is prompted for two data set names. One axis is scaled to one data set, the other axis is scaled to the

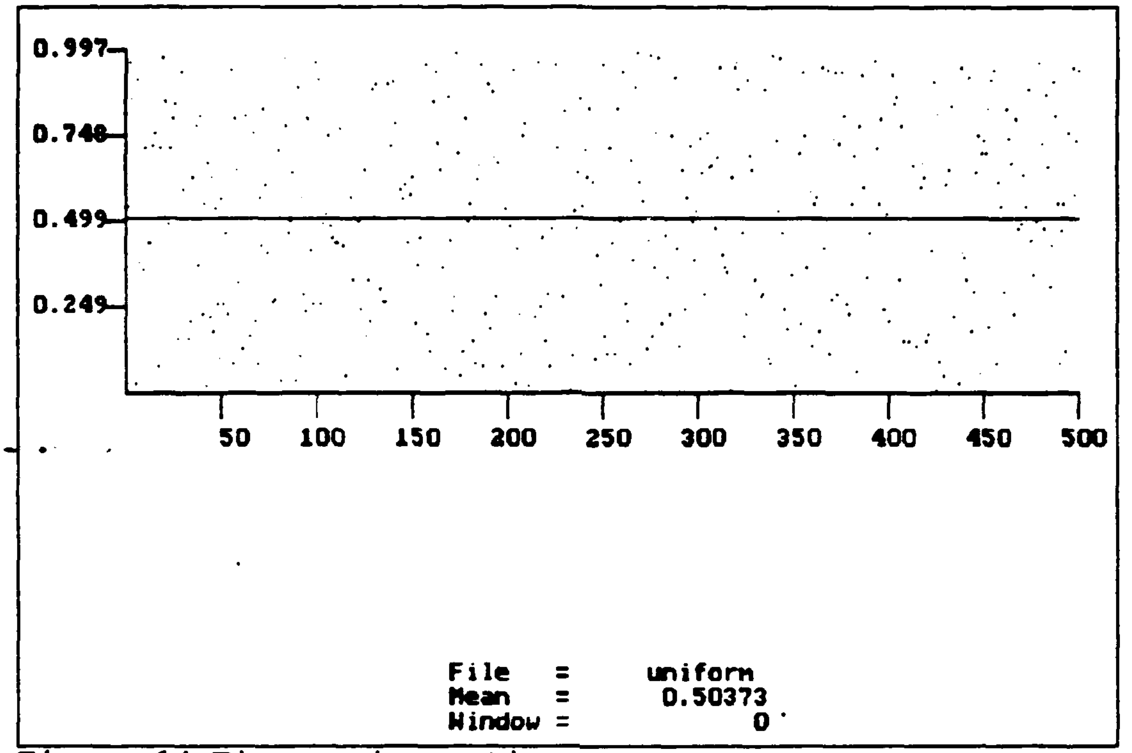


Figure 14 Time series option output.

other data set. The data points are plotted as pairs such as (dataA[1],dataB[1]), (dataA[2],dataB[2]), and so on. The means of the two data sets are drawn as lines through the appropriate axis (these are color coded with the file names on the screen). This option is useful for identifying correlation between two data sets. A discernable pattern suggests that there may be some dependence or relationship between the two variables. Figure 15 shows a graph made by the XYplot option.

<u>**QUANTILE ESTIMATION**</u> - After the user is prompted for the data set name, the quantile estimates will be displayed on the screen. Point estimates and 90% confidence intervals

will be provided for 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 25%, and 75%.

NON-PARAMETRIC PROBABILITY - This routine will prompt the user for a filename, like the QUANTILE routine. Then the routine will prompt for a reference value. The

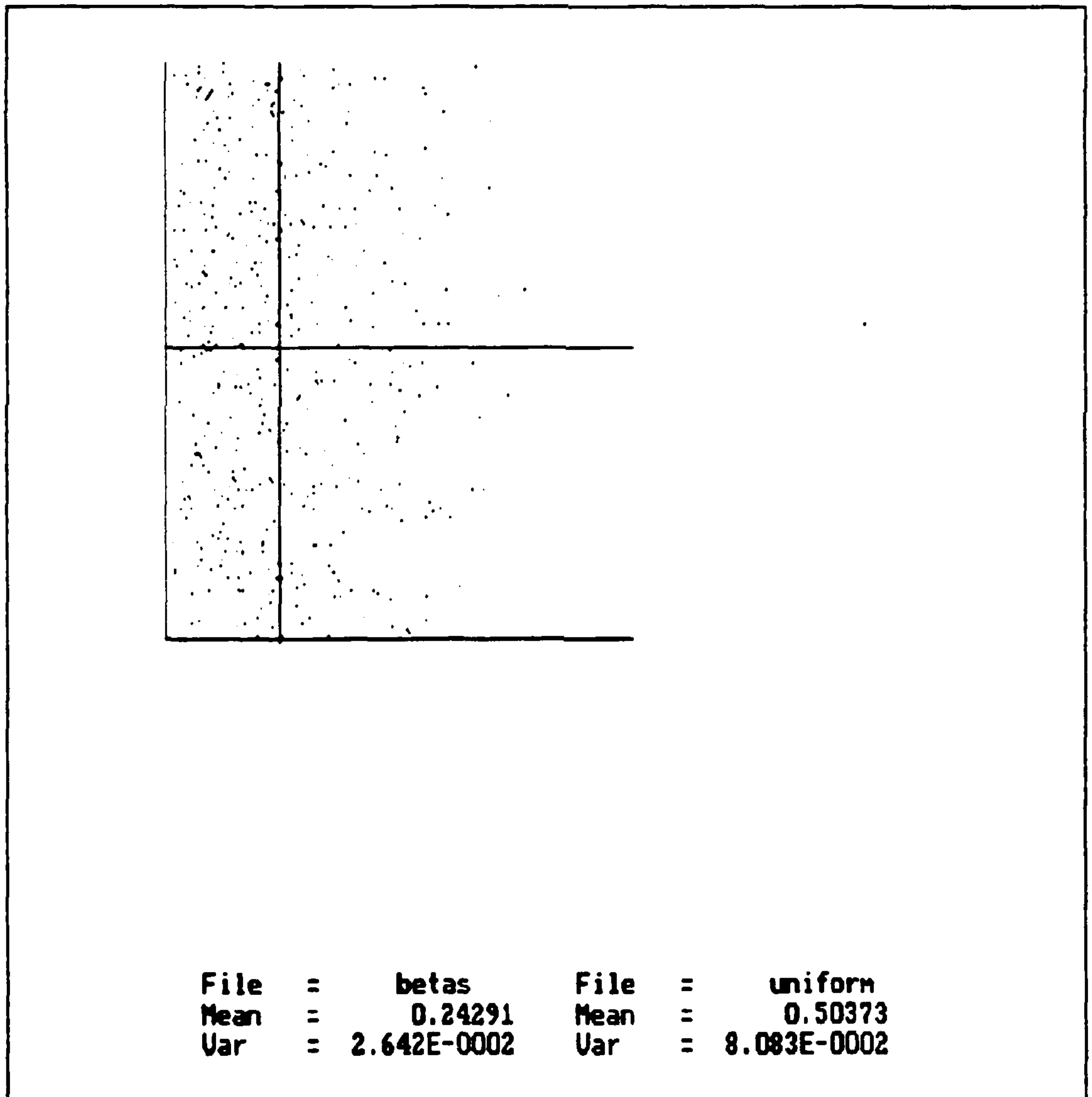


Figure 15 Example of an XY plot.

routine will display the probability that the next value drawn from the data set will be less than the reference value. A 90% confidence interval is provided.

T-TESTING MENU - This menu offers the three T-tests described in Chapter III. For more information concerning the assumptions associated with each test, see Chapter III.

T-TEST 1 - The user will be asked for the names of the two data sets to compare. Next the user will be prompted for the F-test α value. After the F-test is performed with failure to reject, the user will be prompted for the α value for the T-test. The results will be displayed.

T-TESTS 2&3 - The user will be asked for the names of the two data sets to compare. Next the user will be prompted for the T-test α value. The results will be displayed.

FILES MENU - This menu handles importing and exporting ASCII text files and checking the contents of the current disk drive.

READ ASCII - Reads a single column of textual numbers into a data set file. Multiple columns and nonnumeric characters are not allowed. The user is prompted for the name of the ASCII file to read (include the extension when answering this prompt) and then the name under which to store the data set.

WRITE ASCII - Writes a single column of textual numbers into an ASCII file. The user is prompted for the name of the data set file holding the information and then the name of the ASCII file to write (include the extension when answering this prompt).

SET DIRECTORY - Provides a list of the files on the current disk drive that have the .SET extension.

DISK DIRECTORY - Provides a list of the files on the current disk drive according to the file specification entered by the user. For example, to see all the files that have the .DAT extension, enter *.DAT at the file specification prompt.

RANDOM DEVIATES MENU - This menu handles the routines that generate random deviates. The user may write deviates to a file or use them to simulate Life Cycle Costs.

RANDOM DEVIATE FILES - The first three options, Uniform Random, Normal Random, and Generate Betas prompt the user for the appropriate distribution parameters, how many deviates to generate, and the name of the .SET file in which to save the deviates.

MULTI-NORMAL - Generates vectors of dependent normal variates. First the user is prompted for the number of variables in the dependent set, ten is the maximum allowed.

Next the user is prompted for the mean of each variable. After the means are entered, the user is prompted to enter the covariances of the variables. The user is also asked how many vectors to generate. Each set of samples is written as a row vector to the file MULTNORM.DAT.

SIMULATE COSTS - This is the routine that generates Monte Carlo samples of LCC's. The user will be prompted for the name of the system (.STM) file in which the costs are described. See DESCRIBE SYS under the DATA menu for more information. The user will then be prompted for the number of runs, 2500 is the maximum. Finally the user is asked for a file name for the resulting cost estimates.

TUTORIAL

This section of the users' manual is a walk through of the software with a numerical example. A system will be described, entered into the program, and its cost simulated. Let it be clear that this example is grossly over simplified, but it will serve to exercise all the routines of the program. The statistical description procedures are not walked through; only data organization, entry, and simulation is covered here.

THE SYSTEM - John is starting a flying club. He needs to estimate the cost of purchasing and operating a fleet of 6 small aircraft with a life expectancy of ten years. From data about past purchases and operation of similar aircraft John has developed a set of equations representing the costs associated with this fleet of aircraft.

John will have two years of setup and aircraft acquisition, after which the fleet of aircraft will be put into service for ten years. So the entire process will stretch out for twelve years. The current interest rate is 9.5%, and is expected to hold steady for at least twelve years. Following are the equations and their explanations.

The first cost incurred is a setup fee, money needed up front for maintenance equipment and facility renovation. John knows how much this will cost as he has contracted this out, having already negotiated a package price of \$32,000. This cost is incurred in the first year:

$$C_{SETUP} = X_1$$

where

$$X_1 = 32{,}000$$

Next John must purchase the aircraft. The cost of the aircraft fleet has been estimated by the following equation (CER):

$$C_{AIRCRAFT} = X_1^{\beta 1} * X_2^{\beta 2}$$

where

X_1= personnel capacity of aircraft
X_2= thickness of aluminum skin
β_1= estimated at 5.2
β_2= estimated at 0.5
cov($\underline{\beta}$)= estimated at 1= 1.7, 2= 0.05, 1,2= 0.02
MSE = 1.2

John has decided that X_1 will be 4 people. The aircraft manufacturer has notified John that the thickness of the aluminum sheeting (X_2) is usually uniformly distributed between 0.25" and 0.37". Since the aircraft must be purchased after the first year of setup, this cost will be incurred in year 2.

The next cost is the maintenance of the aircraft. It has been shown that the maintenance and operation cost for six aircraft of this type can be forecasted by the following equation:

$$C_{M\&O} = \beta_1 X_1 + \beta_2 X_2^{\alpha 2}$$

where

X_1= flying hours per plane per year
X_2= average humidity over aircraft life
β_1= estimated at 1,380
β_2= estimated at 22,000
cov($\underline{\beta}$)= estimated at 1= 205, 2= 1307, 1,2= 125.9
α_2 = 0.5
MSE = 15,700

Having researched flying clubs in other areas of similar size and demographic composition, John has estimated the flying hours per aircraft per year to be beta distributed between 1,000 and 1,500 hours, with α = 0.5 and β = 1.5 (beta type 3, see figure 11). The local weather archives reveal that the area's average relative humidity over a ten year span is beta distributed between 0.5 and 0.8, with parameters α = 4.5 and β = 1.5 (beta type 7, see figure 11). Since the aircraft will not fly for the first two years, the maintenance and operation costs will be incurred from year three through year twelve.

The last cost John has to worry about is a set of replacement engines. The FAA has made a ruling that small aircraft engines and their propeller speed reduction gears must be replaced after each five years of duty. John has negotiated with the local aircraft parts retailer and has settled on a price scale for the replacement engines. The scale depends on the number of engines purchase. The more you buy, the cheaper they are:

$$C_{1\ ENGINE} = X_1^{\beta 1} * X_2^{\beta 2}$$

where

$C_{1\ ENGINE}$ = average cost per unit
X_1 = number of engines purchased (lot size)
X_2 = number reduction gears per engine
β_1 = estimated at 0.95
β_2 = estimated at 0.3
$cov(\beta)$ = estimated at 1= 0, 2= 0.05, 1,2= 0
MSE = 1,200

This is a learning curve CER. John will be buying 6 engines (X_1) each having 4 reduction gears (X_2). Since the original engines will be replaced five years after start of service, these new engines must be bought in year 7. Note that C is the average cost per unit. The cost of this cost component will be figured by mulitplying that average cost per unit by the number of units to be purchaes, X_1.

SETTING UP SPENDING TIMELINES

Now that all the costs are broken out, the value of NOCOST, PI, CON, and PO must be determined for each cost.

COST 1: SETUP - Figure 16 shows the spending timeline for this cost. The setup will occur in year 1, so the bill will be paid at the end of that year. Since this bill will be paid in its entirety the first year, there are no periods of NOCOST, PI or PO. There will simply be constant spending

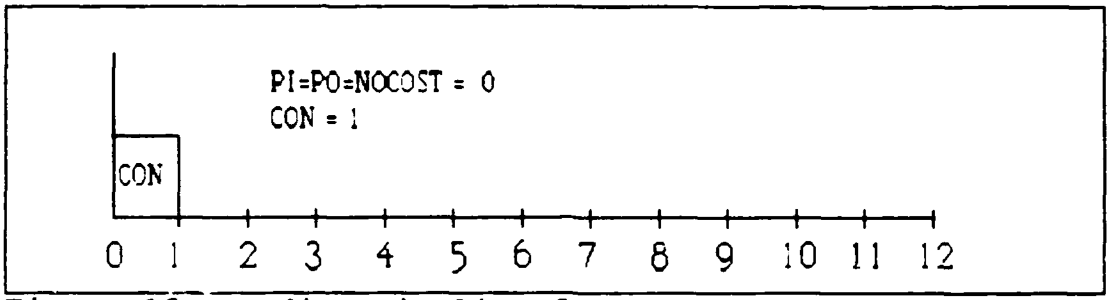


Figure 16 Spending timeline for Cost 1.

in year 1. So the value of CON is 1.

COST 2: AIRCRAFT PURCHASE - Figure 17 shows the spending timeline for this cost. The purchase will occur in year 2, so the bill will be paid at the end of that year.

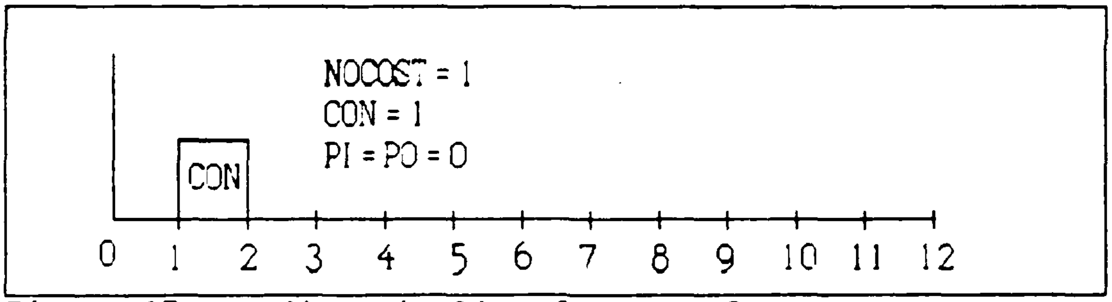


Figure 17 Spending timeline for Cost 2.

This is just like the case of setup above, except the lump sum is paid in year two. Since no money is due in year 1, the NOCOST period is 1 year. The entire cost will be paid in the single year following the NOCOST period (year two) so the CON period is 1 year long.

COST 3: MAINTENANCE AND OPERATION - Figure 18 shows the spending timeline for this cost. The aircraft will begin to fly in year three. Since no money will be spent

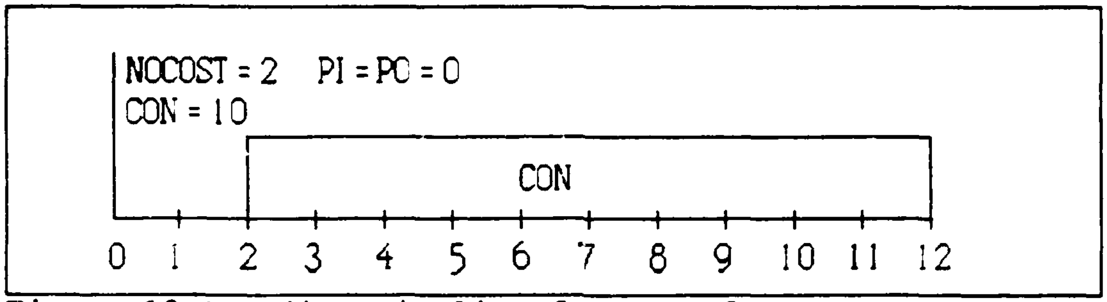


Figure 18 Spending timeline for Cost 3.

for M&O in years 1 and 2, the NOCOST period is 2 years. The maintenance costs will be incurred evenly over the operating life of the aircraft, years 3 through 12, or for 10 years. So the CON period is 10 years. Again there are no PI and PO periods.

COST 4: ADDITIONAL ENGINE PURCHASE - Figure 19 shows the spending timeline for this cost. The purchase of all the additional engines will occur in the fifth year of

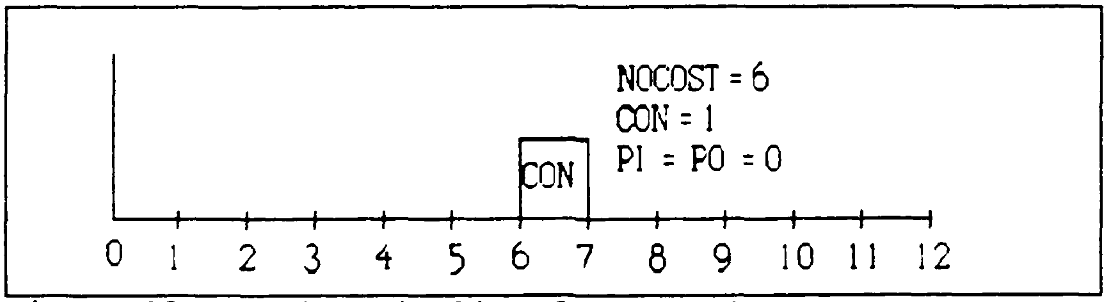


Figure 19 Spending timeline for Cost 4.

aircraft operation, year 7. So the bill will be paid at the end of that year. Since no money is due in years 1 through

6, the NOCOST period is 6 years. The entire cost will be paid in the single year following the NOCOST period (year two) so once again the CON period is 1 year long.

Table 1 lists the values of NOCOST, PI, CON, and PO for each of the costs described above:

Table 1

Cost	NOCOST	PI	CON	PO
SETUP	0	0	1	0
AIRCRAFT PURCHASE	1	0	1	0
MAINTENANCE & OPS	2	0	10	0
REPLACEMENT ENGINES	6	0	1	0

DATA ENTRY

To enter the data describing the system cost components, start the program by typing its name, THESIS. Select DATA from the opening menu by pressing D, or by using the down arrow key to highlight the DATA option, and pressing CR. Now select the DEFINE SYS option from the DATA menu by pressing D. Now you are ready to begin entering costs.

Begin by entering the only single variable cost component, setup costs. Remember that this cost was a constant. Select VARs by pressing V. When prompted for a file name, enter JOHNFLY. Next you are prompted for the number of variables. Respond to the prompt by entering the number 1, because there is only 1 single variable cost component (the others are CER's).

A new screen appears and you are prompted for the type of the variable. Since our variable is a constant, enter a 0 (see Figure 11). When prompted for the constant value, enter 32000 (no commas). Next you are prompted for NOCOST, PI, CON, and PO in that order. Enter the values 0, 0, 1, and 0 in that order, pressing CR after each (see Table 1). Since there are no more single variable cost components, the program returns to the DEFINE SYS menu.

To save the information you have entered so far, press the S key to select SAVE. You are again prompted for a file name, but this time the name JOHNFLY is offered in parentheses as the default. Since JOHNFLY is the name you want, simply press the CR to accept it.

Next you need to enter the CER's. Select CER from the menu by pressing C. Again you are prompted for a file name, press CR to accept the default. When prompted for the number of CER's, enter the total, 3. Next enter the number of the CER you want to describe. Start with 1, which will be the MAINTENANCE AND OPERATIONS CER.

In response to the next prompt, enter the number of explanatory variables (number of β parameters), 2. Next is the sequence of time parameter prompts for this CER. Enter the NOCOST, PI, CON, and PO values as they are asked for, just like in the single variable case. Next the screen clears and you are prompted for the type of the CER; regular (linear), natural logarithm, or learning curve. Select regular by pressing R.

The next group of prompts pertains to the explanatory variables of the CER. For each variable you are prompted for the type, high, and low (or mean and variance for normals) just like with the single variables discussed above. Since X_1 is distributed beta (α=0.5,β=1.5) enter 3 for the type (see Figure 11). Next enter 1000 and 1500 as the low and high values. Since no power transformation is desired, enter 1.0 at the α prompt. For the next explanatory variable, follow the same sequence, except enter 0.5 for α value since that power transformation is indicated by the CER describing the maintenance costs.

After you have described the explanatory variables, you will be prompted for the estimates of the β parameters. Enter 1380 for the first β and 22000 for the second. Next you are prompted for the covariances. Be careful to note which covariance you are being prompted for. First the cov[1,1] appears. Enter 205 since it is the variance of β_1. Next the cov[1,2] prompt appears. Enter 125.7. Finally the cov[2,2] prompt appears, so enter 1307, the variance of β_2. The last prompt is for the MSE. Enter 15700.

To enter the next two CER's follow the same steps. When entering the aircraft cost CER be sure to select natural logarithm as the CER type. Describe the X variables as the beta distributed variables they are. The program will handle the logarithms and exponentiation. Be sure to enter 1.0 for the transformation α's.

For the replacement engines CER, select learning curve as the CER type. Be sure X_1, the first explanatory variable, is the number of units to purchase. The CER outcome, $C_{1\ ENGINE}$ must be multiplied by X_1 to get the total cost of the entire lot of engines, since the CER describes the average cost per unit (engine).

The last step in data entry is to enter the current interest rate. Select RATE from the DEFINE SYS menu. Enter the APR, 9.5. Now save the system file one last time by pressing S and and backup to the main menu using the B key.

RUNNING THE MONTE CARLO SIMULATION

To run the simulation, proceed to the RANDOM DEVIATES menu by selecting R and the main menu. Now select S to simulate costs. When prompted for the file name containing the system information (CER's, rate, etc.) enter JOHNFLY. Next you are prompted for the number of runs to perform, or the number of estimates to make. Enter any integer between

1 and 2500. You must also enter the name of the data set in which to store the cost estimates. You may choose any name, but it is best to keep the same name as the .STM file containing the CER information. Enter JOHNFLY. This will not erase the system information file.

SEEDS

The seed is set to a default of 12345 when the program is initiated. If you run an LCC simulation today with the default seed, and simulate the same system next week with the defalut seed, the output numbers will be exactly the same. You may change the seed upon initiating the program to give different random deviates. Changing the seed is not a dangerous procedure. The seed may be set to any integer between 1 and 32000.

OUTPUT ANALYSIS

You are now ready to use the statistical description routines provided by the program. For information concerning the significance of each routine see Chapter III. For specific program operation information see the functions section of this appendix.

APPENDIX B: RANDOM DEVIATE GENERATOR OUTPUT

OVERVIEW

The purpose of this appendix is to demonstrate the capabilities of the deviate generators used in the model building program. Checks of mean, variance, and serial autocorrelation are performed on each generator. There are more powerful tests for specific distributions available but they have not been performed. The purpose of this appendix is not to prove the theoretical accuracy of the random deviate sampling procedures, but to demonstrate that they have been coded according to the references provided, and that they have no major flaws. For more rigorous validation of the sampling procedures see the appropriate references.

The following sample statistics are provided via STATISTIX II. Additional statistics and graphs are provided from the model builder statistical functions, helping to validate by comparison those statistical functions that have been repeated).

UNIFORM(0,1)

Source: Press.

Type:

500 element test set:	Observed	Expected
mean	0.5037	0.5000
var	0.0808	0.0833
low	0.0004	0.0000
high	0.9970	1.0000

Figures 20 and 21 are graphical depictions of the output deviates, created by the model builder program. Figure 18 shows the first 22 serial autocorrelations for the 500 element test set, as calculated by STATISTIX II.

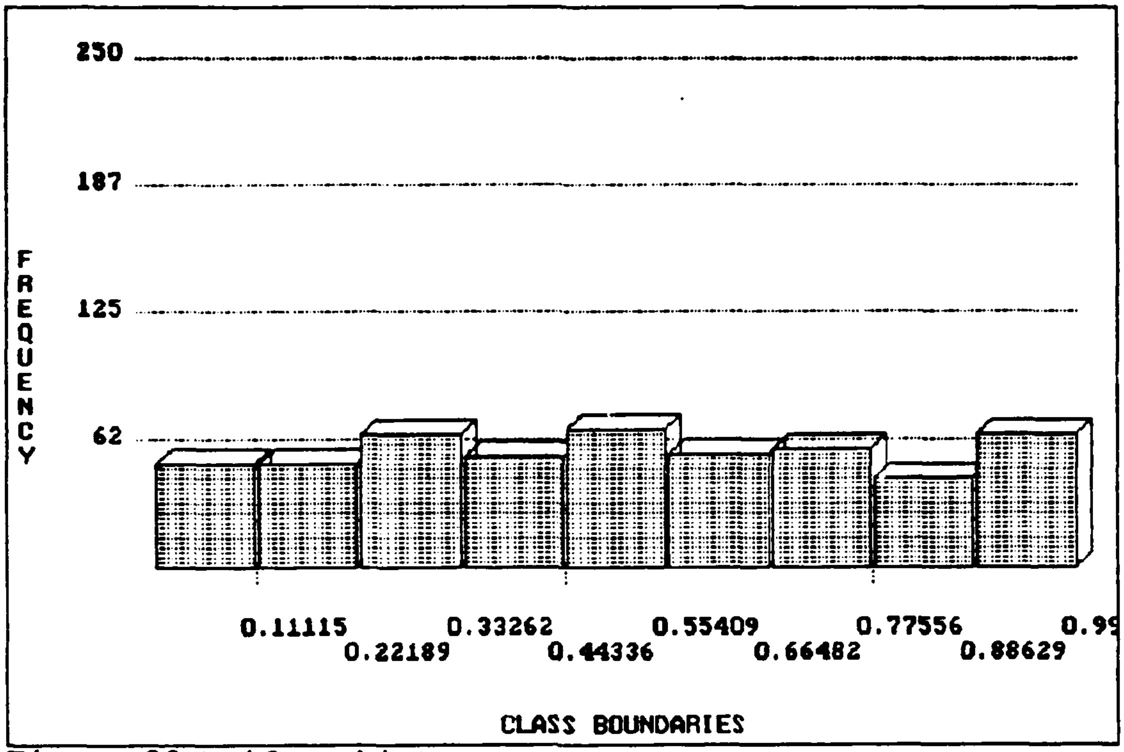


Figure 20 Uniform histogram

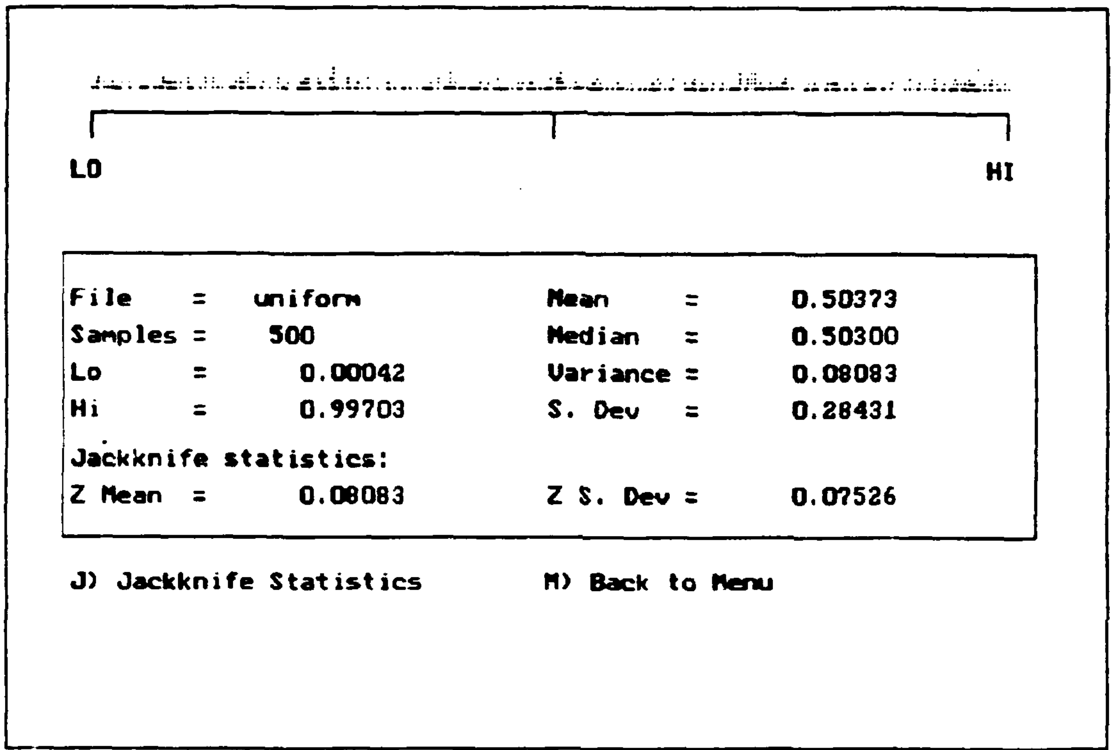


Figure 21 Uniform moments.

```
                 AUTOCORRELATION PLOT FOR UNIFORM

            -1.0 -0.8 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6
 LAG   CORR.
+----+----+----+----+----+----+----+----+----+----+
   1  -0.021                          >** <
   2   0.022                          > **<
   3  -0.017                          > * <
   4   0.063                          > **<
   5  -0.028                          >** <
   6   0.043                          > **<
   7   0.005                          > * <
   8  -0.087                          >** <
   9   0.051                          > **<
  10   0.051                          > **<
  11   0.084                          > **<
  12   0.006                          > * <
  13   0.021                          > **<
  14   0.035                          > **<
  15   0.008                          > * <
  16  -0.038                          >** <
  17  -0.011                          > * <
  18  -0.026                          >** <
  19  -0.089                          >** <
  20   0.096                          > **>
  21  -0.014                          > * <
  22   0.008                          > * <
  23   0.004                          > * <
  24  -0.048                          >** <
  25  -0.091                          >** <

MEAN OF THE SERIES        4.883E-01
STD. DEV. OF SERIES       2.924E-01
NUMBER OF CASES             500
```

Figure 22

NORMAL(0,1)

Source: Ross.

Type:

500 element test set:	Observed	Expected
mean	0.0052	0.0000
var	0.9820	1.0000

Figures 23 and 24 are graphical depictions of the output deviates, created by the model builder program. Figure 25 shows the first 25 serial autocorrelations for the 500 element test set, as calculated by STATISTIX II.

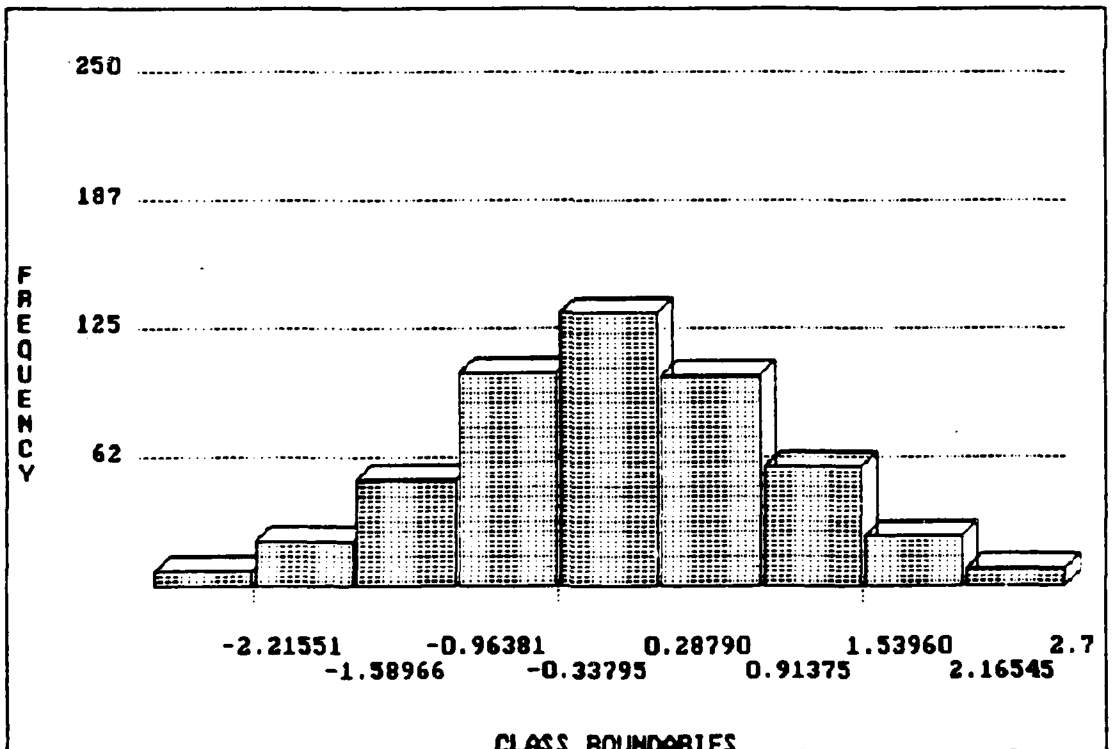
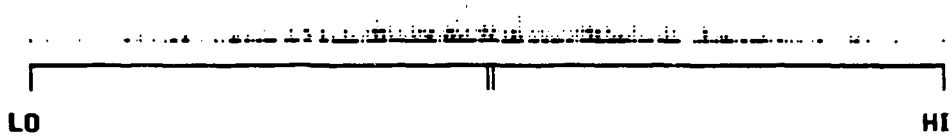


Figure 23 Normal histogram.



File =	normal	Mean =	0.00516
Samples =	500	Median =	-0.02558
Lo =	-2.84136	Variance =	0.98128
Hi =	2.79131	S. Dev =	0.99060

Jackknife statistics:

Z Mean =	0.98128	Z S. Dev =	1.33552

J) Jackknife Statistics   M) Back to Menu

Figure 24 Normal moments.

```
                AUTOCORRELATION PLOT FOR NORMAL

              -1.0 -0.8 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6
 LAG   CORR.
+----+----+----+----+----+----+----+----+----+----+
   1  -0.083                              >** <
   2   0.022                              > **<
   3   0.090                              > **>
   4   0.003                              > * <
   5  -0.011                              > * <
   6   0.034                              > **<
   7  -0.020                              >** <
   8   0.066                              > **<
   9  -0.023                              >** <
  10  -0.031                              >** <
  11   0.028                              > **<
  12   0.015                              > * <
  13  -0.038                              >** <
  14   0.025                              > **<
  15   0.074                              > **<
  16  -0.034                              >** <
  17   0.005                              > * <
  18  -0.013                              > * <
  19  -0.015                              > * <
  20  -0.019                              > * <
  21   0.006                              > * <
  22  -0.069                              >** <
  23   0.004                              > * <
  24  -0.059                              >** <
  25   0.008                              > * <

MEAN OF THE SERIES          5.160E-03
STD. DEV. OF SERIES         0.990
NUMBER OF CASES               500
```

Figure 25

BETA(α=1.5,β=4.5) ON (0,1) INTERVAL

Source: Ross, Fishman.

Type: Acceptance-Rejection.

500 element test set:	Observed	Expected
mean	0.2447	0.2500
var	0.0258	0.0268
low	0.0048	0.0000
high	0.7109	1.0000

Figures 26 and 27 are graphical depictions of the output deviates, created by the model builder program. Figure 28 shows the first 25 serial autocorrelations for the 500 element test set, as calculated by STATISTIX II. Note that the 20th autocorrelation appears significant. Remembering the way risk builds when more than one confidence interval is considered simultaneously we could calculate that the probability of at least one autocorrelation being out of its 90% CI when no actual autocorrelations exist is over 0.95!

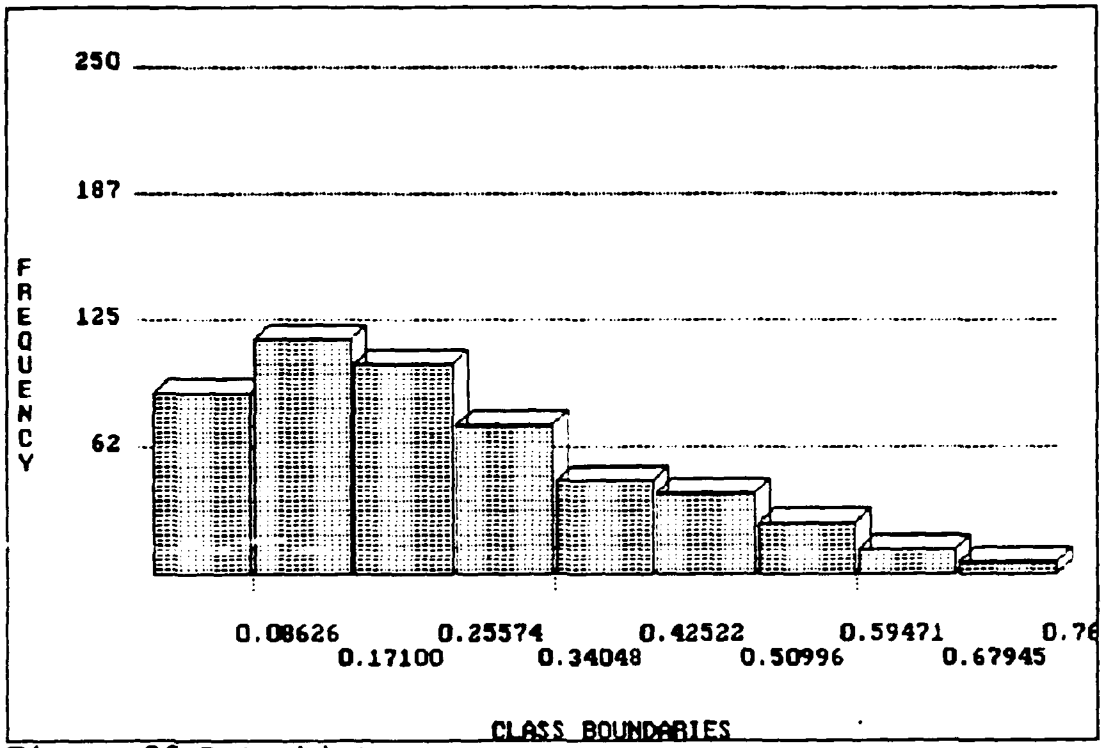
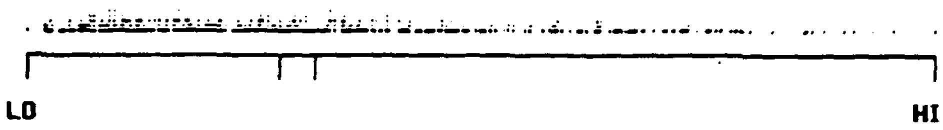


Figure 26 Beta histogram.



File	=	betas	Mean	=	0.24291
Samples	=	500	Median	=	0.21280
Lo	=	0.00152	Variance	=	0.02642
Hi	=	0.76419	S. Dev	=	0.16254

Jackknife statistics:

Z Mean	=	0.02642	Z S. Dev	=	0.03701

J) Jackknife Statistics   M) Back to Menu

Figure 27 Beta moments.

```
                  AUTOCORRELATION PLOT FOR BETA

            -1.0 -0.8 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6
 LAG   CORR.
+----+----+----+----+----+----+----+----+----+----+
   1    0.053                          > **<
   2   -0.022                          >** <
   3   -0.018                          > * <
   4   -0.028                          >** <
   5    0.050                          > **<
   6    0.028                          > **<
   7    0.052                          > **<
   8   -0.088                          >** <
   9   -0.064                          >** <
  10    0.081                          > **<
  11   -0.018                          > * <
  12   -0.012                          > * <
  13    0.063                          > **<
  14    0.001                          > * <
  15    0.039                          > **<
  16    0.007                          > * <
  17    0.026                          > **<
  18    0.023                          > **<
  19    0.018                          > * <
  20    0.102                          > **>*
  21   -0.025                          >** <
  22   -0.036                          >** <
  23   -0.067                          >** <
  24   -0.004                          > * <
  25    0.056                          > **<

MEAN OF THE SERIES          2.447E-01
STD. DEV. OF SERIES         1.605E-01
NUMBER OF CASES               500
```

Figure 28

MULTIVARIATE NORMAL

Source: IMSL User Guide

Type:

500 element test set:		Observed	Expected
mean	x1	4.985	5.000
	x2	10.09	10.00
	x3	15.03	15.00

Covariances	Observed			Expected		
	2.957	0.578	1.994	3.0	1.0	2.0
	0.578	8.338	2.413	1.0	9.0	3.0
	1.994	2.413	4.912	2.0	3.0	5.0

APPENDIX C: TURBO PASCAL 4.0 SOURCE CODE

```
{$S+}     {Stack checking on}
{$N+}     {numeric coprocessor yes}
{$M 64000,0,655360}


PROGRAM thesis;

Uses
  Crt,
  Dos,
  PRINTER,
  Graph,
  davemenu, (* original menuing unit written by me     *)
  davestat; (* original unit written by me,houses many statistical routines *)

(***********************************************************************)
(*                                                                     *)
(* Note: the type and variable declarations, along with many of the   *)
(*       statistical and file handling routines used in this program  *)
(*       are in the unit DAVESTAT.  Some other routines along with all *)
(*       the homemade scrolling menu control routines are in the DAVEMENU *)
(*       unit. Ssince those units have been included with the USES     *)
(*       statement, the program acts as if they were listed here.     *)
(*                                                                     *)
(***********************************************************************)


procedure multinormal(var betas:doubvect;chol:tensq);
(* This is an original procedure written for multinormal sampling using the*)
(* cholesky square root of the covariance matrix. See IMSL for algorithm.  *)
(* This routine is used for generating dependent betas for cers evaluation.*)
var
    n,x                :integer;
    temp2,temp         :double;
begin
n:=trunc(betas[0]);  (* This is the number of betas in this CER *)
mat2.matrix:=chol;   (* Put the cholesky square root of the cov matrix in MAT2 *)
mat2.rowsize:=n;     (* These next 4 lines setup the sizes of working matrices *)
mat2.colsize:=n;
mat1.colsize:=n;
mat1.rowsize:=1;
(* draw the independent normals and put them in a vector *)
for x:= 1 to n do begin
  temp        := ran3(seed);
  temp2       := ran3(seed);
  mat1.matrix[1,x] := sqrt(-2*ln(temp))*sin(2*pi*temp2);
end;
(* Postmultiply independent  normals by cholesky square root of the covariance matrix *)
MULTmat;
(* Now add in the means to complete the dependent multinormal samples*)
for x:=1 to n do
  betas[x] := mat3.matrix[1,x] + betas[x];
end;


PROCEDURE MANUAL(SETG:INFO;VAR NUMARRAY:VECT;NUMG:INTEGER;VAR BOUNDARIES:twenvect);
(* this allows the user to enter his own class boundaries for the *)
(* frequency histogram routine.                                   *)
VAR X,Y       :INTEGER;
    MIN,WIDTH : double;
    go        :boolean;
```

```
(* original *)
BEGIN
  FOR X:= 1 TO NUMG DO
  BEGIN
    WRITE('Upper boundary for class ',X,': ');doubleread(BOUNDARIES[X]);
    writeln('     (inclusive)');
    writeln;
  END;

  for x:=1 to 20 do (* initialize the observed frequency vector *)
    numarray[x]:=0;
  numarray[0]:=1;

  for x:=1 to numg do begin (* Now count the observed frequencies, on class at a time     *)
    go:=true;                                    (* The data will be sorted before it  *)
    for y:= numarray[0] to setg.size do          (* is sent to this routine, so using  *)
      if (setg.data[y]<=boundaries[x]) and go then  (* the go flag allows me to make only *)
        numarray[x]:=numarray[x]+1               (* 1 complete pass through the data to*)
      else go:=false;                            (* count class frequencies.           *)
    numarray[0]:=numarray[0]+numarray[x];
  end;
END;


(* original *)
PROCEDURE autoclass(SETG:INFO;VAR NUMARRAY:VECT;NUMG:INTEGER;VAR BOUNDARIES:twenvect);
(* this automatically sets the calss boundaries for the histogram *)
(* it divides the data range into equal calss widths              *)
(* The data is sorted before it comes to this routine, like the routine above. *)
VAR X,Y    :INTEGER;
    MIN,WIDTH : double;
    cumfreq  :twenvect;
    stuff    :filename;
    go       :boolean;
BEGIN
  MIN   := SETG.DATA[1];
  WIDTH := (SETG.DATA[SETG.SIZE] - MIN)/NUMG;

  FOR X := 1 TO (NUMG) DO
      BOUNDARIES[X]:= MIN+WIDTH*X;
  for x:=1 to 20 do
    numarray[x]:=0;
  numarray[0]:=1;

  for x:=1 to numg do begin (* counting class frequencies just like procedure above *)
    go:=true;
    for y:= numarray[0] to setg.size do
      if (setg.data[y]<=boundaries[x]) and go then
        numarray[x]:=numarray[x]+1
      else go:=false;
    numarray[0]:=numarray[0]+numarray[x];
  end;
END;


(* deQue *)
PROCEDURE ANNXAXIS(XORI,YORI,XLEN,NUMX:INTEGER;XTEXTARR:ANNARRAYTYPE);
(* annotates the x axis for graphs *)
VAR y1,TEXTLENGTH,realxg,J,NUMTODO:INTEGER;
    SPACING                     :double;
BEGIN
  SPACING:= XLEN/NUMX;
  NUMTODO := NUMX +1;
  FOR j:= 1 TO NUMTODO DO
    BEGIN
      TEXTLENGTH := LENGTH(XTEXTARR[J]);
      REALXG := round(XORI+(J-1)*(SPACING)-(8*textlength/2));
      y1:=280;
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      if odd(j) then yl := 290;
      outtextxy(realxg,yl,xtextarr[j]);
    END;
  XTEXTARR[0]:='CLASS BOUNDARIES';
  outtextxy(280,320,xtextarr[0]);
END;


(* deQue *)
PROCEDURE ANNYAXIS(XORI,YORI,YLEN,NUMY:INTEGER;YTEXTARR:ANNARRAYTYPE);
(* annotates the y axis for graphs *)
VAR TEXTLENGTH,XTEXT,YTEXT,J,NUMTODO:INTEGER;
    SPACING,REALXG,REALYG                    :double;
BEGIN
  SPACING:= YLEN/NUMY;
  NUMTODO := NUMY + 1;
  FOR J:= 1 TO NUMTODO DO
    BEGIN
      TEXTLENGTH := LENGTH(YTEXTARR[J]);
      REALXG := XORI - (TEXTLENGTH * 8.0) -15;
      REALYG := YORI-SPACING*(J-1)-4;
      outtextxy(round(realxg),round(realyg),ytextarr[j]);
    END;
  YTEXTARR[0]:='FREQUENCY',
  TEXTLENGTH := LENGTH(YTEXTARR[0]);
  FOR j:= 1 TO TEXTLENGTH DO
      outtextxy(30,120+j*10,ytextarr[0][j]);
END;


(* deQue *)
PROCEDURE  AXISTEXT(VAR GTEXTARR:ANNARRAYTYPE;NUMG:INTEGER;LOWVAL,HIVAL:double;
                    REALFORMAT:BOOLEAN);
(* writes the text at the x axis *)
VAR INTERVAL,REALVAL:double;
    INTVAL,J         :INTEGER;
BEGIN
  gtextarr[1]:=' ';
  INTERVAL := (HIVAL - LOWVAL)/NUMG;
  IF REALFORMAT THEN
    FOR J:= 1 TO NUMG DO
      BEGIN
        REALVAL := LOWVAL + j * INTERVAL;
        STR(REALVAL:12:5,GTEXTARR[J+1])
      END
  ELSE
    FOR J:= 1 TO NUMG DO
      BEGIN
        INTVAL := TRUNC(0.5*(LOWVAL +TRUNC(INTERVAL)*J));
        STR(INTVAL:3,GTEXTARR[J+1]);
      END;
END;



(* deQue *)
PROCEDURE  MANXAXIS(VAR GTEXTARR:ANNARRAYTYPE;NUMG:INTEGER;BOUNDARIES:twenvect;
(* writes the x axis text when manual class boundaries are used *)
                    REALFORMAT:BOOLEAN);
VAR INTERVAL,REALVAL:double;
    INTVAL,J         :INTEGER;
BEGIN
  gtextarr[1]:=' ';
  IF REALFORMAT THEN
    FOR J:= 1 TO NUMG DO
       BEGIN
```

```
      STR(BOUNDARIES[J]:12:5,GTEXTARR[J+1])
    END
  ELSE
    FOR J:= 1 TO NUMG DO
      BEGIN
        INTVAL := TRUNC(BOUNDARIES[J]);
        STR(INTVAL:3,GTEXTARR[J+1]);
      END;
END;


(* deQue *)
PROCEDURE DOXAXIS(XORI,YORI,XLEN,NUMX:INTEGER);
(* this actually draws the lines for the x axis itself *)
VAR X,J,K :INTEGER;
    TEMP : double;
BEGIN
  LINE(XORI,YORI,XORI+XLEN,YORI);
  FOR j:= 1 TO NUMX DO
    BEGIN
      TEMP := XLEN/NUMX*J;
      X := XORI + TRUNC(TEMP);
      LINE(X,YORI,X,YORI+7);
    END
END;


(* deQue *)
PROCEDURE DOYAXIS(XORI,YORI,YLEN,NUMY,XLEN:INTEGER);
(* just like doxaxis except for the y axis *)
VAR Y,J,K :INTEGER;
    TEMP : double;
BEGIN
  LINE(XORI,YORI,XORI,YORI-YLEN);
  FOR j:= 1 TO NUMY DO
    BEGIN
      TEMP :=round(YLEN/NUMY)*J;
      Y    := YORI - ROUND(TEMP);
      LINE(XORI-10,Y,XORI+XLEN,Y);
    END
END;


procedure graphix;
(* sets up the computer for the EGA 640x480 color mode *)
var
  GraphDriver,Graphmode,Errorcode        :integer;  { The Graphics device driver }
begin
  (* INITIALIZE THE EGA 4 COLOR GRAPHICS SCREEN 600h X 350v  *)
  graphdriver:=4;
  graphmode:=1;
  InitGraph(graphdriver,graphmode,'');  { activate graphics }
  ErrorCode := GraphResult;             { error? }
  if ErrorCode <> grOk then  begin
    Writeln('Graphics error: ', GraphErrorMsg(ErrorCode));
    Halt(1);
  end;
end;


(* highly modified deQue *)
PROCEDURE HISTOGRAM;
(* draws a frequency histogram based on a data set     *)
VAR NUMARRAY                              :VECT;
    BOUNDARIES                            :twenvect;
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    GTEXTARR                                     :ANNARRAYTYPE;
    XORI,YORI,XLEN,YLEN,X,Y                      :INTEGER;
    NUMX,NUMY,ULX,ULY,LRX,LRY,J,MAXCLASS         :INTEGER;
    LOX,HIX,LOY,HIY,SCALEX,SCALEY,BARWIDTH       :double;
    REPLY,REPLY2,AUTO,PRYNT                      :CHAR;
    REALFORMATX,REALFORMATY                      :BOOLEAN;
    setg                                         :infoptr;
    p                                            :pointer;
BEGIN
  mark(p);
  new(setg);
  setwindow(36,10,78,18);
  READIN(setg^);
  IF (not EXIST(setg^.name)) or (setg^.SIZE<=2) THEN begin
    release(p);
    exit;
  end;
  MAXCLASS:=0;
  writeln;
  repeat
    write('How many classes?  (5 20): ');intread(numx);writeln;
  until (numx>4) and (numx<21);

  writeln;
  WRITE('Do you want a printout? : ');PRYNT:=READKEY;writeln(' ',prynt);
  writeln;
  IF NUMX<=0 THEN  NUMX:=1;
  write('Automatic classing? : ');AUTO:=READKEY;writeln(' ',auto);
  writeln;

  NUMY:= 4;
  FOR X:= 0 TO NUMX DO  NUMARRAY[X]:=0;
  WRITE('        -- Please Wait --            ');
  SORTHR(setg^);
  if upcase(auto)='Y' THEN  autoclass(setg^,NUMARRAY,NUMX,BOUNDARIES)
  ELSE begin
   MANUAL(setg^,NUMARRAY,NUMX,BOUNDARIES);
   WRITE('        -- Please wait --            ');
 end;
  FOR X:= 1 TO NUMX DO
    IF NUMARRAY[X] > MAXCLASS THEN  MAXCLASS := NUMARRAY[X];
  XORI   := 100; (* left edge of graph *)
  YORI   := 259; (* top  edge of graph *)
  XLEN  := 480;  (* length of x axis   *)
  YLEN  := 210;  (* length of y axis   *)
  REALFORMATX:= TRUE;  (* says to show x axis label numbers as reals    *)
  REALFORMATY:= FALSE; (* says to show y axis label numbers as integers *)
  graphix;       (* initialize the graphics card mode *)
  SETCOLOR(RED); (* these three lines draw the x and y axes in red *)
  DOXAXIS(XORI,YORI,XLEN,NUMX);      (* draw x axis *)
  DOYAXIS(XORI,YORI,YLEN,NUMY,XLEN);(* draw y axis *)
  LOX:=setg^.DATA[1]; (* these two lines get hi and low values, data is sorted *)
  HIX:=setg^.DATA[setg^.SIZE];
  SETCOLOR(WHITE);

  (* this next block figures class boundaries, observed frequencies, and writes the axis text*)
  IF UPCASE(AUTO)='Y'  THEN     AXISTEXT(GTEXTARR,NUMX,LOX,HIX,REALFORMATX)
  ELSE MANXAXIS(GTEXTARR,NUMX,BOUNDARIES,REALFORMATX);
  ANNXAXIS(XORI,YORI,XLEN,NUMX,GTEXTARR);
  AXISTEXT(GTEXTARR,NUMY,0,setg^.SIZE,REALFORMATY);
  ANNYAXIS(XORI,YORI,YLEN,NUMY,GTEXTARR);
  SCALEY := 2.0*YLEN/setg^.SIZE;
  BARWIDTH := XLEN/NUMX;

  (* now draw the bars for the histogram based on observed frequencies per class *)
  FOR j:= 1 TO NUMX DO BEGIN
    (* this code calculates the proper hieght for each                *)
    (* bar of the histogram and draws each bar in 3-dimensional form *)
    ULX := XORI + TRUNC(BARWIDTH * (J-1));
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    ULY := TRUNC(YORI - NUMARRAY[J] * SCALEY);
    LRX := XORI + TRUNC(BARWIDTH*J);
    bar3D(ULX+1,ULY,LRX-1,YORI,8,TRUE);
    (*BAR  (ULX+1,ULY,LRX-1,YORI); TO HAVE 2-D RATHER THAN 3-D *)
  END;

  IF UPCASE(PRYNT)='Y' THEN  PRTSC;
  PAUSE:=READKEY;
  RESTORECRTMODE;
  release(p);
END;



(* original *)
PROCEDURE MOMENTS;
(* calculates mean,var,median,and jackknifing for a data set *)
(* along with a horizontal plot for identifying outliers    *)
(* and checking the spread of the data                        *)
VAR PRYNT,jac                                        :CHAR;
    I,J,L,R,X,MID,XORI,YORI,XLEN,x1,y1               :integer;
    GraphDriver,Graphmode,Errorcode                  :INTEGER;
    NUM,MEDIAN,LOX,HIX,XSCALE,MEAN,VARIANCE          :double;
    STUFF                                            :FILENAME;
    pixelcolor                                       :word;
    setg                                             :infoptr;
    p                                                :pointer;
BEGIN
  mark(p);
  new(setg);
  setwindow(36,10,78,18);
  READIN(setg^);
  IF (not EXIST(setg^.name)) or (setg^.SIZE <= 2) THEN begin
    release(p);
    exit;
  end;
  writeln;
  WRITE('Do you want a printout? : ');PRYNT :=READKEY;
  writeln;
  write(       -- Please wait --        ');
  MEANVAR(setg^,MEAN,VARIANCE);
  SORTHR(setg^);
  LOX    :=setg^.DATA[1];
  HIX    :=setg^.DATA[setg^.SIZE];
  XORI   := 60;
  YORI   :=148;
  XLEN   := 480;
  if hix-lox < 0.00001 then begin
    writeln('No spread in the data, a. . ',lox);
    pause:=readkey;
    release(p);
    exit;
  end;
  XSCALE:=XLEN/(HIX-LOX);

  (* find the median *)
  IF ODD(setg^.SIZE) THEN  MEDIAN := setg^.DATA[(setg^.SIZE + 1) DIV 2]
  ELSE  BEGIN
    MID := setg^.SIZE DIV 2;
    MEDIAN := (setg^.DATA[MID] + setg^.DATA[MID + 1]) / 2.0
  END;

  (* DRAW THE NUMBER LINE *)
  graphix;
  SETCOLOR(WHITE);
  LINE(XORI,YORI,XORI+XLEN,YORI);
  LINE(XORI,YORI,XORI,YORI+10);
  LINE(XORI+XLEN,YORI,XORI+XLEN,YORI+10);
  OUTTEXTXY(XORI-10,YORI+20,'LO');
```

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OUTTEXTXY(XORI+XLEN-10,YORI+20,'HI');

(* PLOT THE MEAN TICK MARK  and the Median tick mark *)
SETCOLOR(RED);
LINE(ROUND((MEAN-LOX)*XSCALE)+XORI,YORI+10,ROUND((MEAN-LOX)*XSCALE)+XORI,YORI);
setcolor(lightgreen);
LINE(ROUND((Median-LOX)*XSCALE)+XORI,YORI+10,ROUND((MEdian-LOX)*XSCALE)+XORI,YORI);

(* NOW PLOT EACH OF THE DATA POINTS *)
SETCOLOR(YELLOW);
FOR j:= 1 TO setg^.SIZE DO begin
  x1:=round((setg^.DATA[J]-LOX)*XSCALE)+XORI;
  y1:=YORI-10;
  pixelcolor:=getpixel(x1,y1);
  while pixelcolor=yellow do begin (* IF THIS POINT IS ALREADY PLOTTED,     *)
    y1:=y1-2;                      (* THEN GO UP TWO DOTS TO INDICATE THAT *)
    pixelcolor:=getpixel(x1,y1);   (* MORE THAN ONE POINT IS PLOTTED HERE  *)
  end;
  PUTPIXEL(x1,y1,yellow);
END;

(* Now draw the tabular data box at the bottome of the screen  *)
SETCOLOR(WHITE);
LINE(45,205,45,320);
LINE(45,205,555,205);
LINE(555,205,555,320);
LINE(45,320,555,320);

(* Now convert all the data to strings and write the strings *)
                                 outtextxy(50,220,'File     =   '+setg^.NAME);
STR(setg^.SIZE:6,STUFF);          outtextxy(50,235,'Samples = '+STUFF);
STR(lox:12:5,stuff);             OUTTEXTXY(50,250,'Lo      = '+stuff);
STR(hix:12:5,stuff);             outtextxy(50,265,'Hi      = '+stuff);
SETCOLOR(RED);
STR(mean:12:5,stuff);            OUTTEXTXY(300,220,'Mean     = '+stuff);
setcolor(lightgreen);
STR(MEDIAN:12:5,STUFF);          OUTTEXTXY(300,235,'Median   = '+stuff);
setcolor(white);
STR(VARIANCE:12:5,STUFF);        OUTTEXTXY(300,250,'Variance = '+STUFF);
STR(SQRT(VARIANCE):12:5,STUFF);  OUTTEXTXY(300,265,'S. Dev   = '+STUFF);
                                 OUTTEXTXY(50,335,'J) Jackknife Statistics       M) Back to Menu');
jac:=readkey;
IF UPCASE(JAC)='J' THEN BEGIN
  setcolor(white+blink);
                                  outtextxy(50,285,'Jackknife statistics:');
  JACK(setg^,MEAN,VARIANCE);
  STR(MEAN:12:5,STUFF);           outtextxy(50,300,'Z Mean  = '+stuff);
  str(sqrt(variance):12:5,stuff);outtextxy(300,300,'Z S. Dev = '+stuff);
  pause:=readkey;
end;
IF UPCASE(PRYNT)='Y' THEN PRTSC;
restorecrtmode;
release(p);
END;




(* original *)
PROCEDURE PLOTit;
(* this plots one data set against another, basically an x y plot *)
VAR stuff                                           :filename;
    tempset,setg,seth                               :infoptr;
    PRYNT                                           :CHAR;
    Y,J,YLEN,L,R,X,MID,XORI,YORI,XLEN,x1,y1         :INTEGER;
    xscale,YSCALE,NUM,MEDIAN,LOX,HIX,MEAN,VARIANCE  :double;
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    hi,hmean,hvariance,loh,hih                         :double;
    p                                                  :pointer;
BEGIN
  mark(p);
  new(tempset);new(setg);new(seth);
  setwindow(36,10,78,18);
  READIN(setg^);
  iF (not EXIST(setg^.name)) or (setg^.SIZE <= 2) THEN  begin
    release(p);
    exit;
  end;
  readin(seth^);
  iF (not EXIST(seth^.name)) or (seth^.SIZE <= 2) THEN  begin
    release(p);
    exit;
  end;
  writeln;
  WRITE('Do you want a printout?  : ');PRYNT:=READKEY;write(prynt);
  writeln;
  writeln(    -- PLEASE WAIT --');
  WRITELN;
  MEANVAR(setg^,MEAN,VARIANCE);
  tempset^:=setg^;
  SORTHR(setg^);
  LOX:=setg^.DATA[1];
  HIX:=setg^.DATA[setg^.SIZE];
  setg^:=tempset^;
  MEANVAR(seth^,hMEAN,hVARIANCE);
  tempset^:=seth^;
  SORTHR(seth^);
  LOh:=seth^.DATA[1];
  HIh:=seth^.DATA[seth^.SIZE];
  seth^:=tempset^;
  XORI    := 80;
  YORI    :=210;
  XLEN   :=250;
  YLEN:=190;
  if hix>hih then hih:=hix;
  if hih>hix then hix:=hih;
  YSCALE:=YLEN/(HIx);
  xscale:=xlen/(hih);

  (* draw the axes *)
  graphix;
  SETCOLOR(WHITE);
  LINE(XORI,YORI,XORI+XLEN,YORI);
  LINE(XORI,YORI,XORI,YORI-YLEN);


  (* PLOT THE MEAN LINE and WRITE THE MEAN AND FILE NAME *)
  SETCOLOR(RED);
  LINE(XORI+1,ROUND(YORI-MEAN*YSCALE),XORI+XLEN,ROUND(YORI-MEAN*YSCALE));
  str(mean:12:5,stuff);outtextxy(300,330,'Mean    =  '+stuff);
  OUTTEXTXY(300,320,'File    =       '+setg^.name);
  str(variance:12,stuff);outtextxy(300,340,'Var     =  '+stuff);

  SETCOLOR(green);
  LINE(round(xORI+hMEAN*xSCALE),yori+1,round(XORI+hmean*xscale),YORI-ylen);
  str(hmean:12:5,stuff);outtextxy(100,330,'Mean    =  '+stuff);
  OUTTEXTXY(100,320,'File    =       '+seth^.name);
  str(hvariance:12,stuff);outtextxy(100,340,'Var     =  '+stuff);
  setcolor(white);

  (* NOW PLOT EACH OF THE DATA POINTS *)
  SETCOLOR(YELLOW);
  FOR j:= 1 TO setg^.size DO BEGIN
    x1:=round(XORI+seth^.data[J]*XSCALE);
    y1:=YORI-TRUNC(setg^.DATA[J]*YSCALE);
    PUTPIXEL(x1,y1,yellow);
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  end;
  IF UPCASE(PRYNT)='Y' THEN PRTSC;
  pause:=readkey;
  restorecrtmode;
  release(p);
END;



(* original *)
(* this plots the data in a time series fashion       *)
(* it can plot a moving average of any odd size window *)
PROCEDURE TIMEPLOT;
VAR AVERAGES,setg                                        :INFoptr;
    MOVING,PRYNT,jac                                     :CHAR;
    XSCALE,WINDOW,Y,J,YLEN,L,R,X,MID,XORI,YORI,XLEN,x1,y1 :INTEGER;
    SUM,YSCALE,NUM,MEDIAN,LOX,HIX,MEAN,VARIANCE          :double;
    STUFF                                                :FILENAME;
    point1,point2                                        :integer;
    pixelcolor                                           :word;
    p                                                    :pointer;
BEGIN
  mark(p);
  new(setg);new(averages);
  setwindow(36,10,78,18);
  READIN(setg^);
  if (not EXIST(setg^.name)) or (setg^.SIZE <= 2) THEN begin
    release(p);
    exit;
  end;
  window:=0;
  averages^:=setg^;
  writeln;
  WRITE('Do you want a printout?  : ');PRYNT:=READKEY;
  writeln;
  WRITE('Use moving averages?  : ');MOVING:=READKEY;writeln(' ',moving);
  writeln;
  IF UPCASE(MOVING)='Y' THEN BEGIN
    WINDOW:=2;
    while not odd(window) do begin
      WRITE('Window size for averages (ODD): ');intREAD(WINDOW);
      writeln;
    END;
    writeln('    -- Please wait --    ');
    for x:= 1 to (setg^.size-window) do begin
    (* now calculate the moving average values *)
      sum:=0;
      for y:= 1 to window do
        sum:= sum+setg^.data[x+y];
        averages^.data[x+(trunc(window/2)+1)]:=sum/window;
    END;
  END
  Else writeln('    -- Please Wait --    ');
  MEANVAR(setg^,MEAN,VARIANCE);
  SORTHR(setg^);
  LOX:=setg^.DATA[1];
  HIX:=setg^.DATA[setg^.SIZE];
  XORI   := 80;
  YORI   :=210;
  XLEN  := 500;
  YLEN:=140;
  YSCALE:=YLEN/(HIX);
  graphix;
  (* DRAW THE NUMBER LINE *)
  XSCALE:=TRUNC(500/setg^.SIZE);
  if xscale=0 then xscale:=1;
  SETCOLOR(WHITE);
  LINE(XORI,YORI,XORI+XLEN,YORI);
  LINE(XORI,YORI,XORI,YORI-YLEN);
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```
 FOR X:= 1 TO TRUNC(10/XSCALE) DO BEGIN
   LINE(XORI+X*50*XSCALE,YORI,XORI+X*50*XSCALE,YORI+10);
   STR(X*50:3,STUFF);
   OUTTEXTXY(XORI+X*50*XSCALE-8,YORI+15,STUFF);
 END;
 FOR X:= 1 TO 4 DO BEGIN
   LINE(XORI,YORI-X*35,XORI-10,YORI-X*35);
   STR(((HIX/4)*X):9:3,STUFF);
   OUTTEXTXY(XORI-80,YORI-(X*35)-4,STUFF);
 END;

 (* PLOT THE MEAN LINE and WRITE THE MEAN AND FILE NAME *)
 SETCOLOR(RED);
 LINE(XORI+1,ROUND(YORI-MEAN*YSCALE),XORI+XLEN,ROUND(YORI-MEAN*YSCALE));
 str(mean:12:5,stuff);outtextxy(250,330,'Mean   = '+stuff);
 setcolor(white);
 OUTTEXTXY(250,320,'File    =      '+setg^.name);
 str(window:12,stuff);outtextxy(250,340,'Window = '+stuff);

 (* NOW PLOT EACH OF THE DATA POINTS *)
 SETCOLOR(YELLOW);
 point1:=1;
 POINT2:=setg^.SIZE;
 IF WINDOW<> 0 THEN begin
 (* calculate the first and last points who will        *)
 (* be plotted depending on the window size,            *)
 (* since some data points do not have a moving average *)
   POINT1:=POINT1+1+TRUNC(WINDOW/2);
   point2:=point2-trunc(window/2);
 end;
 FOR j:= point1 TO POINT2 DO BEGIN
   x1:=round(XORI+J*XSCALE);
   y1:=YORI-TRUNC(averages^.DATA[J]*YSCALE);
   PUTPIXEL(x1,y1,yellow);
 end;
 IF UPCASE(PRVNT)='Y' THEN PRTSC;
 pause:=readkey;
 restorecrtmode;
 release(p);
END;



(* original *)
PROCEDURE COMBINE;
(* this appends a second data set to the end of a data set *)
VAR X           : INTEGER;
    set1,set2   : infoptr;
    p           : pointer;
BEGIN
  mark(p);
  new(set1);new(set2);
  setwindow(36,10,78,18);
  TWOSETS(set1^,set2^);
  IF (not EXIST(set1^.name)) or (not EXIST(set2^.name)) THEN exit;
  WRITE('Name the new set : ');READLN(set2^.NAME);
  writeln;
  FOR X:= 1 TO set1^.SIZE DO
    set2^.DATA[X+set1^.SIZE] := set1^.DATA[X];
  set2^.SIZE := set1^.SIZE + set2^.SIZE;
  SAVE(set2^);
  release(p);
END;


 (* original *)
```

```
Procedure ftestvar(seta,setb:info;var equal:boolean);
(* this performs an f-test for equal variances between two data sets *)
var pvalue,alpha,fstat,vara,varb,meana,meanb :double;
    temp                    :string[15];
    df1,df2,code            :integer;
begin
equal:=true;
writeln;
writeln('Performing F test for Equal variances ...');
writeln;
meanvar(seta,meana,vara);
meanvar(setb,meanb,varb);
(* calculate the test statistic and set the degrees of freedom *)
if vara>=varb then begin
  fstat:=vara/varb;
  df1:=seta.size-1;
  df2:=setb.size-1;
  end
else begin
  fstat:=varb/vara;
  df1:=setb.size-1;
  df2:=seta.size-1;
end;
(* now calculate the p value *)
pvalue:=fvalue(fstat,df1,df2);
write('Enter alpha level : ');doubleread(alpha);
writeln;
if pvalue > alpha then
  writeln('F test passed ...')
else begin
  equal:=false;
  writeln('F test failed ...');
end;
writeln('var A = ',vara:12:5);
writeln('var B = ',varb:12:5);
writeln('Any key continues ...');
pause:=readkey;
end;


(* original *)
procedure ttest;
(* a t-test for two sets with equal variances,independent sets *)
var equal                                                  :boolean;
    alpha,pvalue,tstat,spooled,diff,vara,varb,meana,meanb  :double;
    df                                                     :integer;
    seta,setb                                              :infoptr;
    p                                                      :pointer;

begin
mark(p);
new(seta);new(setb);
tWOSETS(seta^,setb^);
IF (not EXIST(seta^.name)) or (not EXIST(setb^.name))then begin
  release(p);
  exit;
end;
(* first check to see if variances are equal *);
ftestvar(seta^,setb^,equal);
if not equal then begin
  release(p);
  exit;
end;
meanvar(seta^,meana,vara);
meanvar(setb^,meanb,varb);
diff:=meana-meanb;
df:=seta^.size+setb^.size-2;
(* find pooled standard dev *)
```

```
spooled:=sqrt(((seta^.size-1)*vara + (setb^.size-1)*varb)/df);
if spooled < 0.0000001 then begin
  writeln('s pooled = ',spooled:12:5);
  writeln;
  writeln('s pooled < 0.0000001 ...');
  writeln('leaving the test routine ...');
  pause:=readkey;
  release(p);
  exit
end;
(* calculate the test statitic *)
tstat:=abs(diff/spooled*sqrt(1/seta^.size+1/setb^.size)); (* use this to integrate t and get p value *)
writeln;
writeln('Now performing T test.');
write('Enter the alpha level : ');doubleread(alpha);
pvalue:=tvalue(tstat,df);
if pvalue > alpha/2 then begin
  writeln('No evidence to reject hypothesis ...');
end
else begin
    writeln;
    writeln('Reject the null hypothesis (A=B)');
    writeln('  means are statistically different ...');
end;
writeln('mean A = ',meana:12:5);
writeln('mean B = ',meanb:12:5);
writeln;
pause:=readkey;
release(p);
end;



(* original *)
procedure t2test;
(* A t-test for independent sets, equal variances not needed *)
(* This works like the procedure above with different variance formula *)
var equal                                                   :boolean;
    stanerr,pvalue,alpha,tstat                              :double;
    spooled,diff,vara,varb,meana,meanb                      :double;
    df                                                      :integer;
    seta,setb                                               :infoptr;
    p                                                       :pointer;

begin
mark(p);
new(seta);new(setb);
twosets(seta^,setb^);
IF not EXIST(seta^.name) then exit;
if not exist(setb^.name) then exit;
meanvar(seta^,meana,vara);
meanvar(setb^,meanb,varb);
diff:=meana-meanb;
stanerr:= sqrt(vara/seta^.size+varb/setb^.size);
if stanerr < 0.0000001 then begin
  writeln('standard error = ',stanerr:12:5);
  writeln;
  writeln('standard error < 0.0000001 ...');
  writeln('leaving test routine ...');
  pause:=readkey;
  exit;
end;
tstat:=ABS(diff/sqrt(vara/seta^.size+varb/setb^.size)); (* use this to integrate t and get p value *)
df:=seta^.size-1;
if df > setb^.size-1 then df:=setb^.size-1;
pvalue:=tvalue(tstat,df);
writeln;
write('Enter the alpha: ');doubleread(alpha);
if pvalue > alpha then begin
```

```
  writeln;
  writeln('No evidence to reject hypothesis ...');
end
else begin
    writeln;
    writeln('Reject the null hypothesis (A=B)');
    writeln('  means are statistically different ...');
end;
writeln('mean A = ',meana:12:5);
writeln('mean B = ',meanb:12:5);
writeln;
pause:=readkey;
release(p);
end;


(* original *)
procedure t3test;
(* weakest test, independence not needed *)
(* Works basically like the above tests but requires paired data *)
var equal                                              :boolean;
    standev,sum,sumsq,alpha,pvalue,tstat,meana         :double;
    x,samples                                          :integer;
    seta,setb                                          :infoptr;
    p                                                  :pointer;
begin
mark(p);
new(seta);new(setb);
twosets(seta^,setb^);
IF not EXIST(seta^.name) then exit;
if not exist(setb^.name) THEN exit;
samples:=seta^.size;
if samples > setb^.size then samples:=setb^.size;
if samples < 2 then exit;
sum:=0;
sumsq:=0;
for x:=1 to samples do begin
  seta^.data[x]:=seta^.data[x]-setb^.data[x];
  sum:=sum+seta^.data[x];
  sumsq:=sumsq+sqr(seta^.data[x]);
end;
meana:=sum/samples;
standev:=sqrt((samples*sumsq-sqr(meana))/ (samples*(samples-1)) );
if standev< 0.0000001 then begin
  writeln('standev =',standev:12:5);
  writeln;
  writeln('standev < 0.0000001 ...');
  writeln('leaving the test routine ...');
  pause:=readkey;
  exit;
end;
tstat:=ABS(meana/(standev * sqrt(samples)));
pvalue:=tvalue(tstat,samples-1);
writeln;
write('Enter the alpha : ');doubleread(alpha);
if pvalue > alpha then begin
  writeln,
  writeln('No evidence to reject hypothesis ...');
end
else begin
    writeln;
    writeln('Reject the null hypothesis (A=B)');
    writeln('  means are statistically different ...');
end;
writeln('mean = ',meana:12:5);
writeln;
pause:=readkey;
release(p);
end;
```

```
PROCEDURE uRANDOM;
(* generates a set of uniform samples *)
VAR x      : INTEGER;
    seta   : infoptr;
    p      : pointer;
BEGIN
  mark(p);
  new(seta);
  setwindow(36,10,78,18);
  write('how many?     : ');
  intread(seta^.size);
  if seta^.size>1500 then begin
    writeln('Number set to max of 2500');
    seta^.size:=2500;
  end;
  wRITELN;
  WRITE('Name for data file : ');
  readln(seta^.name);
  setname:=seta^.name;
  writeln;
  for x:= 1 to seta^.size do
    seta^.data[x]:=(ran3(seed));
  save(seta^);
END;


function uniform(hi,low:double):double;
(* returns one uniform random variable *)
BEGIN
  uniform:=ran3(seed)*(hi-low)+low;
END;


function power(number,exponent:double):double;
(* handles exponentiation for positive numbers with any power *)
label 10;
begin
if exponent=0 then
  power:=1
else if number=0 then
  power:=0
else if number > 0.0 then
  power := exp(exponent*ln(number))
else power:=number;
10:end;


function wgrandom(alpha,beta:double):double;
(* Wallaces procedure for generating gamma vars   *)
(* This is called by the beta generating function *)
VAR temp3,temp4,temp2,temp5     :double;
label 10;
BEGIN
10: temp2:=ran3(seed);
    temp3:=int(alpha);
    temp4:=alpha-temp3;
    count:=trunc(temp3);
    temp5:=1;
    for y:= 1 to count do
      temp5:=temp5*ran3(seed);
    if (temp2 <= 1-alpha+temp3) then temp5:=temp5*ran3(seed);
```

```
    temp5:=-1*ln(temp5);
    temp2:=ran3(seed);
    if (temp2 <= power(temp5/temp3,temp4)/(1-temp4+temp4*temp5/temp3)) then
      wgrandom:=temp5*beta
    else goto 10;
END;


function fgrandom(alpha,beta:double):double;
(* fishman's method of generating gamma rv's *)
(* This is called by the beta generating function *)
var temp,temp2:double;
label 10;
begin;
10: temp:=-1*ln(ran3(seed));
    temp2:=ran3(seed);
    if (temp2 <= power(temp/exp(temp+1),alpha-1)) then
      fgrandom:=alpha*temp*beta
      else goto 10;
END;



function betavar(alpha,beta:double):double;
(* This generates beta vars by generating a ratio of gamma vars *)
var temp:double;
begin
  if alpha<1 then temp:=fgrandom(alpha,1)
  else temp:=wgrandom(alpha,1);
  if abs(temp)>0.001 then
    if beta<1 then
      betavar:=temp/(temp+fgrandom(beta,1))
    else betavar:=temp/(temp+wgrandom(beta,1))
  ELSE BETAVAR:=0;
END;


procedure lotsofbetas;
(* generates A SETOF beta deviates *)
VAR x                           :INTEGER;
    seta                        :infoptr;
    p                           :pointer;
    alpha,beta                  :double;
BEGIN
  mark(p);
  new(seta);
  setwindow(36,10,78,18);
  WRITELN;
  write('enter the alpha  : ');
  doubleread(alpha);
  writeln;
  write('enter the beta   : ');
  doubleread(beta);
  WRITELN;
  write('how many?     : ');
  intread(seta^.size);
  if seta^.size > 2500 then begin
    writeln('Number set to max of 2500');
    seta^.size := 2500;
  end;
  count:=seta^.size;
  wRITELN;
  WRITE('Name for data file : ');
  readln(seta^.name);
  setname:=seta^.name;
  writeln;
```

```
  for x:= 1 to trunc(seta^.size) do begin
    seta^.data[x]  :=  betavar(alpha,beta);
  end;
  save(seta^);
  release(p);
end;



procedure Nrandom;
(* generates A SETOF normal deviates *)
VAR x                              :INTEGER;
    temp,temp2,mean,variance   :double;
    seta                           :infoptr;
    p                              :pointer;
BEGIN
  mark(p);
  new(seta);
  setwindow(36,10,78,18);
  WRITELN;
  write('enter the mean     : ');
  doubleread(mean);
  writeln;
  write('enter the variance: ');
  doubleread(variance);
  WRITELN;
  write('how many?      : ');
  intread(seta^.size);
  if seta^.size > 2500 then begin
    writeln('Number set to max of 2500');
    seta^.size := 2500;
  end;
  count:=seta^.size;
  WRITELN;
  WRITE('Name for data file : ');
  readln(seta^.name);
  setname:=seta^.name;
  writeln;

  for x:= 1 to trunc(seta^.size/2) do begin
    writeln(x);
    temp  :=ran3(seed);
    temp2 :=ran3(seed);
    seta^.data[x+(trunc(seta^.size/2))]:=  sqrt(-2*ln(temp))*cos(2*pi*temp2);
    seta^.data[x]                      :=  sqrt(-2*ln(temp))*sin(2*pi*temp2);
  end;
  if odd(seta^.size) then begin
    temp:=ran3(seed);
    temp2:=ran3(seed);
    seta^.data[seta^.size]:=sqrt(-2*ln(temp))*sin(2*pi*temp2);
  end;

  for x:= 1 to seta^.size do begin
      seta^.data[x]:= (seta^.data[x]*sqrt(variance))+mean;
      end;
  save(seta^);
  release(p);
end;


function normal(mean,variance:double):double;
(* returns one normal deviate *)
var    temp,temp2,temp3 :double;
BEGIN
    temp  :=  ran3(seed);
    temp2 :=  ran3(seed);
    temp3 :=  sqrt(-2*ln(temp))*cos(2*pi*temp2);
```

```
    normal:=  (temp3*sqrt(variance))+mean;
end;


procedure directory;
(* makes the call to check the disk directory for any file specification *)
var filespec:filename;
begin
  setwindow(36,10,78,18);
  write('Enter Dir mask : ');readln(filespec);
  WINDOW(1,1,80,25);
  showdir(filespec);
end;


(* original *)
procedure average;
(* this procedure averages each term of any number of data sets into one *)
var seta,setb            :infoptr;
    done,numfiles,x      :integer;
    p                    :pointer;
begin
  mark(p);
  new(seta);new(setb);
  setwindow(36,10,78,18);
  numfiles:=1;
  writeln;
  writeln('First file:');
  writeln('***********');
  readin(seta^);
  if not exist(seta^.name) and (seta^.name[1]<>'Q') then BEGIN
    writeln;
    write('Data file does not exist ...');
    PAUSE:=READKEY;
    exit;
  END;
  repeat
    done:=0;
    writeln;
    writeln('Next file:');
    writeln('**********');
    readin(setb^);
    if exist(setb^.name) then begin
      for x:= 1 to seta^.size do
        seta^.data[x]:=seta^.data[x]+setb^.data[x];
      numfiles:=numfiles+1;
    end
    else if (setb^.name<>'Q') and (setb^.name<>'q') then begin
      writeln;
      write('Data file does not exist ...');
      PAUSE:=READKEY;
    END
    else if (setb^.name='Q') or (setb^.name='q') then done:=1;
  until done=1;
  for x:=1 to seta^.size do  seta^.data[x]:= seta^.data[x]/numfiles;
  clrscr;
  write('Name for new set: ');readln(seta^.name);
  save(seta^);
  release(p);
end;


procedure enterrate(var sys:systemrec);
```

```
(* This procedure allows the user to enter or change the interest rate *)
(* associated with a LCC system.                                        *)
var tempname : worrd;
    fil      : file of systemrec;
begin
  setwindow(50,15,78,22);
  WRITEln;
  write('File name? (',sysname,'): ');readln(tempname);
  IF TEMPNAME <> '' THEN
    SysNAME:=TEMPNAME;
  tempname:=SysNAME;
  assign(fil,tempname+'.stm');
  if exist2(tempname+'.stm') then begin
    reset(fil);
    read(fil,sys);
    close(fil);
    writeln;
    writeln(' -- file read -- ');
  end
  else writeln(' -- new file -- ');
  writeln;
  write('interest reate(apr): ');doubleread(sys.rate);
end;


procedure entvars(var sys:systemrec);
(* This routine allows the user to specify what types of single variable *)
(* cost components contribute to the LCC of the system.*)
var countvar : integer;
    tempname : worrd;
    fil      : file of systemrec;
begin
  setwindow(50,15,78,22);
  WRITEln;
  write('File name? (',sysname,') : ');readln(tempname);
  IF TEMPNAME <> '' THEN
    SysNAME:=TEMPNAME;
  tempname:=SysNAME;
  assign(fil,tempname+'.stm');
  if exist2(tempname+'.stm') then begin
    reset(fil);
    read(fil,sys);
    close(fil);
    writeln;
    writeln(' -- file read -- ');
  end
  else writeln(' -- new file -- ');
  writeln;
  write('How many Variables : ');intread(countvar);
  window(1,1,80,25);clrscr;
  setwindow(3,2,78,22);
  writeln('Single Variable Components');
  writeln('**************************');
  writeln;
  FOR X:= 1 TO countvar DO BEGIN
    WRITE(X:2,'     TYPE: ');DOUBLEREAD(sys.VARs[1,X]);
    if SYS.VARS[1,X] = 0 then BEGIN
      WRITE('constant : ');
      DOUBLEREAD(SYS.VARS[2,X])
    END
    ELSE IF SYS.VARS[1,X]<11 THEN BEGIN
      WRITE('      LOW: ');DOUBLEREAD(sys.VARs[2,X]);
      write('       HI: ');DOUBLEREAD(sys.VARs[3,X]);
    END
    ELSE BEGIN
      WRITE('     MEAN: ');DOUBLEREAD(sys.VARs[2,X]);
      write('      VAR: ');DOUBLEREAD(sys.VARs[3,X]);
    END;
      write(' nocost  : ');doubleread(sys.varstime[4,x]);
```

```
      write(' phase in: ');doubleread(sys.varstime[1,x]);
      write(' constant: ');doubleread(sys.varstime[2,x]);
      write('phase out: ');doubleread(sys.varstime[3,x]);
  END;
  sys.vars[1,0]:=countvar;
end;


procedure savesys(sys:systemrec);
(* This procedure saves an LCC system specification to disk *)
VAR OVER        :CHAR;
    tempname    :worrd;
    TEMP2       :FILENAME;
    sysfile     :file of systemrec;
BEGIN
    setwindow(50,15,78,22);
    writeln;
    write('File name? (',sysname,'): ');readln(tempname);
    IF TEMPNAME <> '' THEN
      SysNAME:=TEMPNAME;
    tempname:=SysNAME;
    TEMP2:=CONCAT(tempname,'.Stm');
    IF EXIST2(temp2) THEN
      BEGIN
        WRITE('File Exists, Overwrite?: ');
        OVER:=READKEY;
        writeln;
      END
    ELSE
      OVER:='Y';
    IF UPCASE(OVER) = 'Y' THEN
    BEGIN
      ASSIGN(sysFile,TEMP2);
      REWRITE(sysFile);
      WRITE(sysFile,Sys);
      CLOSE(sysFile);
    END;
END;



procedure entercer(var sys:systemrec);
(* This reads in the Beta Cov matrix, and finds the cholesky square root.  *)
(* This is an original procedure written for cholesky decomposition using  *)
(* the method as explained in  j.h. maindonald's STATISTICAL COMPUTATION   *)
(* It also reads in all other information needed for the CER's of the LCC  *)
(* system to be simulated *)
var
    cer,z,m,x,y,j,k                 :integer;
    temp2,temp,sum,sum2,sum3        :double;
    tempname                        :worrd;
    fil                             :file of systemrec;
    intercept,certype               :char;
begin
  setwindow(50,15,78,22);
  WRITEln;

  write('File name? (',sysname,'): ');readln(tempname);
  IF TEMPNAME <> '' THEN
    SysNAME:=TEMPNAME;
  tempname:=SysNAME;
  assign(fil,tempname+'.stm');
  if exist2(tempname+'.stm') then begin
    reset(fil);
    read(fil,sys);
    close(fil);
    writeln;
    writeln(' -- file read -- ');
```

```
end
else writeln(' -- new file -- ');
writeln;
write('How many CERs : ');intread(x);
if x>20 then begin
  write('X set at upper limit of 20.');
  writeln;
  x:=20;
end;
sys.cervars[0,1,1]:=x;
writeln;
write('Which CER      : ');intread(cer);
if cer>20 then begin
  write('CER# set at upper limit of 20.');
  writeln;
  cer:=20;
end;
window(1,1,80,25);clrscr;
setwindow(3,2,78,22);
writeln('CER Information CER(',cer,')');
writeln('************************');
writeln;
WRITELN;
repeat
  write('Number of β''s (max=9): ');intread(n);
  writeln;
until n<10;
writeln('Time period lengths ...');
writeln;
write('  nocost        : ');doubleread(sys.certime[4,cer]);
write('  phase in      : ');doubleread(sys.certime[1,cer]);
write('  constant      : ');doubleread(sys.certime[2,cer]);
write('  phase out     : ');doubleread(sys.certime[3,cer]);
clrscr;
writeln;
writeln('  R) Regular');
writeln('  N) Natural log');
writeln('  L) Learning curve');
writeln;
repeat
  write('Which type of CER ? : ');certype:=readkey;
  writeln(certype);
  sys.certypes[cer]:=upcase(certype);
until (sys.certypes[cer]='R') or (sys.certypes[cer]='N') or (sys.certypes[cer]='L');
writeln;
write('Is there an intercept term? : ');intercept:=readkey;
writeln;
if (intercept='y') or (intercept='Y') then begin
  writeln;
  writeln('The entercept will be called β',n+1,'.');
  writeln('Enter the intercept value (β',n+1,') :');doubleread(sys.cerbetas[cer,n+1]);
  case certype of
    'R':begin
          sys.cerVARs[cer,n+1,1]:=0;
          sys.cerVARs[cer,n+1,2]:=1.0;
          sys.cerVARs[cer,n+1,3]:=1.0;
          sys.cerVARs[cer,n+1,4]:=1.0;
        end;
    'N':begin
          sys.cerVARs[cer,n+1,1]:=0;
          sys.cerVARs[cer,n+1,2]:=exp(1.0);
          sys.cerVARs[cer,n+1,3]:=exp(1.0);
          sys.cerVARs[cer,n+1,4]:=1.0;
        end;
    'L':begin
          sys.cerVARs[cer,n+1,1]:=0;
          sys.cerVARs[cer,n+1,2]:=exp(1.0);
          sys.cerVARs[cer,n+1,3]:=exp(1.0);
          sys.cerVARs[cer,n+1,4]:=1.0;
```

```
        end;
    end; (* end of case *)
  end; (* end of if *)
  clrscr;
  writeln;
  writeln('Explanatory Variables CER(',cer,')');
  writeln('************************');
  writeln;
  FOR X:= 1 TO n DO BEGIN
    WRITE(X:2,'  TYPE: ');DOUBLEREAD(sys.cerVARs[cer,X,1]);
    WRITE('     LOW: ');DOUBLEREAD(sys.cerVARs[cer,X,2]);
    WRITE('     HI : ');DOUBLEREAD(sys.cerVARs[cer,X,3]);
    write('     α  : ');doubleread(sys.cervars[cer,x,4]);
  END;
  window(1,1,80,25);clrscr;
  setwindow(3,2,78,22);
  writeln('Beta estimates CER(',cer,')');
  writeln('************************');
  writeln;
  For x:= 1 to n do begin
    write('Enter β',x,' :');doubleread(sys.cerbetas[cer,x]);
  end;
  writeln;
  if (intercept='y') or (intercept='Y') then
    n:=n+1;
  sys.cervars[cer,0,1]:=n;
  (* initialize cov matrix *)
  for x:= 1 to n do
    for y:= 1 to n do
      sys.cercovs[cer,x,y]:=0;
  (* read in the cov matrix in triangular form *)
  writeln('Now the Covariances ...');
  if (intercept='y') or (intercept='Y') then
    writeln('Remember, the entercept is called β',n,'.');
  writeln;
  for x:= 1 to n do
    for y:= 1 to x do begin
      write( cov[',x,',',y,'] = ');doubleread(sys.cercovs[cer,y,x]);
    end;
  writeln;
  write('Enter the MSE: ');doubleread(sys.cermse[cer]);
  (* construct the cholesky square root *)
  for x:= 1 to n do begin
    if x>1 then
      for y:= 1 to x-1 do
        for z:= x to n do
          sys.cercovs[cer,x,z]:=sys.cercovs[cer,x,z]-sys.cercovs[cer,y,x]*sys.cercovs[cer,y,z];
    temp:=sqrt(abs(sys.cercovs[cer,x,x]));
    if abs(temp)<=0.001 then temp:=1;
    for y:= 1 to n do
      sys.cercovs[cer,x,y]:=sys.cercovs[cer,x,y]/temp;
  end;
end;




procedure multirandom;
var
    counter,z,n,x,y,j,k          :integer;
    temp2,temp,sum,sum2,sum3     :double;
    betas                        :doubvect;
    tempname                     :worrd;
```

```
(* type as speccified by "tipe" wich is passed in.                *)
(* NOTE: hi and low contain the mean and var for normal variables.  *)
var type2,low2,hi2        : integer;
    tempval               : double;
begin
type2:=trunc(tipe);
case type2 of

   0:sample:=low;

   1:begin
       tempval:=betavar(1.5,0.5);
       tempval:=tempval*(hi-low) + low;
       sample :=power(tempval,transform);
     end;

   2:begin
       tempval:=betavar(1.35,1.35);
       tempval:=tempval*(hi-low) + low;
       sample :=power(tempval,transform);
     end;

   3:begin
       tempval:=betavar(0.5,1.5);
       tempval:=tempval*(hi-low) + low;
       sample :=power(tempval,transform);
     end;

   4:begin
       tempval:=betavar(3.0,1.0);
       tempval:=tempval*(hi-low) + low;
       sample :=power(tempval,transform);
     end;

   5:begin
       tempval:=betavar(2.75,2.75);
       tempval:=tempval*(hi-low) + low;
       sample :=power(tempval,transform);
     end;

   6:begin
       tempval:=betavar(1.0,3.0);
       tempval:=tempval*(hi-low) + low;
       sample :=power(tempval,transform);
     end;

   7:begin
       tempval:=betavar(4.5,1.5);
       tempval:=tempval*(hi-low) + low;
       sample :=power(tempval,transform);
     end;

   8:begin
       tempval:=betavar(4.0,4.0);
       tempval:=tempval*(hi-low) + low;
       sample :=power(tempval,transform);
     end;

   9:begin
       tempval:=betavar(1.5,4.5);
       tempval:=tempval*(hi-low) + low;
       sample :=power(tempval,transform);
     end;

   10:begin
       tempval:=uniform(low,hi);
       sample :=power(tempval,transform);
     end;
```

```
   11:begin
       tempval:=normal(low,hi);
       sample :=power(tempval,transform);
     end;

end; (* of case statement *)
end;
```

```
procedure pval(var amount:double;nocostt,phasein,cons,phaseout,rate:double);
(* This is the present value routine for finding the present value   *)
(* of a future cash stream.  The amount of money, lenght of phasein, *)
(* phaseout, and constant periods are passed in.                     *)
var areapi,areapo,areaco,totalarea                     : double;
    lastcumarea,height,value,nocost                    : double;
    x,le,phi,po,co                                      : integer;
    portion                                            : largevect;
begin
writeln('amount=',amount);
writeln('nocostt=',nocostt);
writeln('phasein=',phasein);
writeln('cons=',cons);
writeln('phaseout=',phaseout);
writeln('rate=',rate);
pause:=readkey;
areapi:=0;
areapo:=0;
areaco:=0;
totalarea:=0;
phi:=trunc(phasein);
po:=trunc(phaseout);
co:=trunc(cons);
nocost:=trunc(nocostt);
height:=1;
(* calculate the total area *)
if phi>0 then
  totalarea:=phi*0.5*height
else phi:=0;
if co>0 then
  totalarea:=totalarea + co*height
else co:=0;
if po>0 then
  totalarea:= totalarea + po*0.5*height
else po:=0;
le:=phi+co+po;
(* calculate the portions *)
if phi<>0 then begin
  lastcumarea:=0;
  for x:= 1 to phi do begin
    portion[x]:=((x*height/phi)*x*0.5-lastcumarea)/totalarea;
    lastcumarea:=portion[x]*totalarea;
  end;
end;
if co<>0 then
  for x:= phi+1 to phi+co do begin
    portion[x]:=height/totalarea;
  end;
if po<>0 then begin
  lastcumarea:=0;
  for x:= le downto le-po+1 do begin
    portion[x]:=((le-x+1)*(le-x+1)*1/po*0.5-lastcumarea)/totalarea;
    lastcumarea:=portion[x]*totalarea;
  end;
end;
```

```
(* claculate the overall pv number *)
value:=0;
for x:= 1 to le do
  value:=value + portion[x]*amount/power((1+rate/100),x+NOCOST);
amount:=value;
end;




procedure montecarlo;
(* This actually runs the show, it calls the routines to  simulate the *)
(* system cost as many times as requested.                            *)
var totalcost,tempcost,tempcost2,firstx    : double;
    run,numruns,counter,counter2,x,y,z     : integer;
    name                                   : worrd;
    fylename                     : filename;
    sysfile                      : file of systemrec; (* the system file store to disk  *)
    systum                       : systemrec;         (* record to hold cost components *)
    betas                        : doubvect;
    tempset                      : ^info;
    tempmat                      : tensq;
    p                            : pointer;


begin
  mark(p),
  (*new(systum);*)
  new(tempset);
  setwindow(30,10,78,20);
  writeln;
  write('System file? :');readln(name);
  fylename:=concat(name,'.stm');
  if not exist2(fylename) then begin
    writeln('That file is not here ...');
    pause:=readkey;
    release(p);
    exit;
  end;
  writeln;
  write('How many runs? :');intread(numruns);
  if numruns>1500 then begin
    numruns:=1500;
    writeln('Runs set at max of 1500.');
  end;
  assign(sysfile,fylename);
  reset(sysfile);
  read(sysfile,systum); (* read the disk file into the system record *)
  for run:= 1 to numruns do begin
    write('.');
    totalcost:=0;

    (* add variable costs to the total cost *)
    counter:=trunc(systum.vars[1,0]); (* number of variable components *)
    for x:= 1 to counter do begin
      tempcost:=sample(systum.vars[1,x],systum.vars[2,x],systum.vars[3,x],1);

pval(tempcost,systum.varstime[4,x],systum.varstime[1,x],systum.varstime[2,x],systum.varstime[3,x],systum.ra
te);
      totalcost:=totalcost + tempcost;
    end;

    (* now add cers to the total cost *)
    counter:=trunc(systum.cervars[0,1,1]); (* number of CERs *)
    for x:= 1 to counter do begin
      counter2:=trunc(systum.cervars[x,0,1]); (* number of input vars for this cer *)
      betas[0]:=counter2;           (* a counter used in multinormal *)
```

```
      for y:= 1 to counter2 do begin (* puts betas and cov in temp variables for use *)
        betas[y]:=systum.cerbetas[x,y];
        for z:= 1 to counter2 do
          tempmat[y,z]:=systum.cercovs[x,y,z];
      end;
      multinormal(betas,tempmat);
      tempcost2:=0;
      for Y:= 1 to counter2 do begin

tempcost:=sample(systum.cervars[x,y,1],systum.cervars[x,y,2],systum.cervars[x,y,3],systum.cervars[x,y,4]);
        if y=1 then firstx:=tempcost; (* store for use in lc cers *)
        if (systum.certypes[x]='L') or (systum.certypes[x]='N') then
          tempcost:=Ln(tempcost);
        tempcost2:=tempcost2+tempcost*betas[y]: (* running total within cer *)
      end;
      tempcost2:=tempcost2+sample(11,0,systum.cermse[x],1.0); (* account for MSE variance of prediction*)
      if (systum.certypes[x]='L') or (systum.certypes[x]='N') then
          tempcost2:=exp(tempcost2);
      if (systum.certypes[x]='L') then
          tempcost2:=tempcost2 * firstx;

pval(tempcost2,systum.certime[4,x],systum.certime[1,x],systum.certime[2,x],systum.certime[3,x],systum.rate)
;
      totalcost:=totalcost+tempcost2;
    end;

    tempset^.data[run]:=totalcost; (* store this observation of total cost *)
  end;
  writeln;
  writeln('Enter name for output set : ');readln(tempset^.name);
  tempset^.size:=numruns;
  save(tempset^);
  release(p);
end;




(*************************************************)
(*                                               *)
(* Everything from here down is menus.  These are *)
(*   the heart of the user interface.  What you   *)
(*   see here are the menu test entries and the   *)
(*   resulting procedures called for each menu    *)
(*   choice.  The actual scrolling of the cursor, *)
(*   first letter selection, and popup windows    *)
(*   are handled in the DAVEMENU unit.            *)
(*                                               *)
(*************************************************)


PROCEDURE enterMENU;
var
    GO,go2       :char;
    wich,temp    :integer;
    p            :pointer;
    TEMPNAME     :WORRD;

BEGIN
  mark(p);
  new(sys);
  sys^.vars[1,0]:=0;
  sys^.cervars[0,1,1]:=0;
  (**********************************)
  wich:=6;
  menu^.left[wich]:=34;
```

```
  menu^.max[wich]:=4;
  menu^.top[wich]:=10;
  menu^.text[1,wich]:='Vars (single) ';
  menu^.text[2,wich]:='Define CERs   ';
  menu^.text[3,wich]:='Interest rate ';
  menu^.text[4,wich]:='Save file     ';
  menu^.text[0,wich]:='Backup        ';
  menu^.text[menu^.max[wich]+1,wich]:=' DEFINE SYSTEM ';
  (**********************************)
  go:=menu^.text[1,wich][1];
  GO2:=menu^.text[1,wich][1];
  temp:=1;
  WHILE upcase(GO) <> 'B' DO  BEGIN
    windo=(1,1,80,25);
    menucontrol(wich,go,go2,temp);
    GO:=UPCASE(GO);
    (**********************************)
    CASE GO OF
      'V' : entvars(sys^);
      'D' : entercer(sys^);
      'I' : enterrate(sys^);
      'S' : savesys(sys^);
    END; (* END OF CASE AND ELSE*)
    (***********************************)
  end;   (* WHILE LOOP END *)
  release(p);
END;   (* PROCEDURE END *)


PROCEDURE testMENU;
var
    GO,go2:char;
    wich,temp:integer;
    tempstring:string15;

begin
  wich:=5;
  (********* CHANGE THESE PARAMETERS TO MAKE A NEW MENU SCREEN *********)
  menu^.left[wich]:=18;
  menu^.top[wich] :=6;
  menu^.max[wich]:=3;
  menu^.text[1,wich]:='Equal var,Ind';
  menu^.text[2,wich]:='Ind. only     ';
  menu^.text[3,wich]:='Samples paired';
  menu^.text[0,wich]:='Backup        ';
  menu^.text[menu^.max[wich]+1,wich]:='     Tests     ';
  (**********************************************************************)
  go:=menu^.text[1,wich][1];
  GO2:=menu^.text[1,wich][1];
  temp:=1;
  WHILE upcase(GO) <> 'B' DO  BEGIN
    windo=(1,1,80,25);
    menucontrol(wich,go,go2,temp);
    GO:=UPCASE(GO);
(**********************************)
    CASE GO OF
      'E':t1test;
      'I':t2test;
      'S':t3test;
      'B':exit;
    end; (* of case *)
(**********************************************************************)
  end; (* while *)
end; (* procedure *)
```

```
PROCEDURE workMENU;
var
    GO,go2:char;
    wich,temp:integer;
    tempstring:string15;

begin
  wich:=4;
  (********* CHANGE THESE PARAMETERS TO MAKE A NEW MENU SCREEN *********)
  menu^.left[wich]:=18;
  menu^.top[wich] :=6;
  menu^.max[wich]:=6;
  menu^.text[1,wich]:='Moments       ';
  menu^.text[2,wich]:='Freq Histogram';
  menu^.text[3,wich]:='Time plot     ';
  menu^.text[0,wich]:='Backup        ';
  menu^.text[4,wich]:='X vs Y Plot   ';
  menu^.text[5,wich]:='Quantiles     ';
  menu^.text[6,wich]:='Nonpar. Prob  ';
  menu^.text[menu^.max[wich]+1,wich]:='  Statistics   ';
  (*********************************************************************)
  go:=menu^.text[1,wich][1];
  GO2:=menu^.text[1,wich][1];
  temp:=1;
  WHILE upcase(GO) <> 'B' DO  BEGIN
    window(1,1,80,25);
    menucontrol(wich,go,go2,temp);
    GO:=UPCASE(GO);
(*********************************)
    CASE GO OF
      'M':moments;
      'F':histogram;
      'T':timeplot;
      'X':plotit;
      'Q':quantiles;
      'N':probability;
    END;  (* END OF CASE *)
(**********************************************************)
  end; (* while *)
end; (* procedure *)



PROCEDURE fileMENU;
var
    GO,go2:char;
    wich,temp:integer;
    tempstring:string15;

begin
  wich:=3;
  (********* CHANGE THESE PARAMETERS TO MAKE A NEW MENU SCREEN *********)
  menu^.left[wich]:=18;
  menu^.top[wich] :=6;
  menu^.max[wich]:=4;
  menu^.text[1,wich]:='Read ASCII    ';
  menu^.text[2,wich]:='Write ASCII   ';
  menu^.text[3,wich]:='Set Directory ';
  menu^.text[4,wich]:='Disk Directory';
  menu^.text[0,wich]:='Backup        ';
  menu^.text[menu^.max[wich]+1,wich]:='     Files     ';
  (*********************************************************************)
  go:=menu^.text[1,wich][1];
```

```
  GO2:=menu^.text[1,wich][1];
  temp:=1;
  WHILE upcase(GO) <> 'B' DO  BEGIN
    window(1,1,80,25);
    menucontrol(wich,go,go2,temp);
    GO:=UPCASE(GO);
(***********************************)
    CASE GO OF
      'S':SHOWDIR('*.set');
      'R':READASCII;
      'W':WRITASCII;
      'D':directory;
    END; (* END OF CASE *)
(************************************************************)
 end;   (* end of while *)
END;       (* end of procedure *)



PROCEDURE randommenu;
var
    GO,go2:char;
    wich,temp:integer;
    tempstring:string15;

begin
  wich:=7;
  (********* CHANGE THESE PARAMETERS TO MAKE A NEW MENU SCREEN *********)
  menu^.left[wich]:=18;
  menu^.top[wich] :=6;
  menu^.max[wich]:=5;
  menu^.text[1,wich]:='Uniform Random';
  menu^.text[2,wich]:='Normal random ';
  menu^.text[3,wich]:='Generate betas';
  menu^.text[4,wich]:='Multi-normal  ';
  menu^.text[5,wich]:='Simulate costs';
  menu^.text[0,wich]:='Backup        ';
  menu^.text[menu^.max[wich]+1,wich]:='     Files     ';
  (*********************************************************************)
  go:=menu^.text[1,wich][1];
  GO2:=menu^.text[1,wich][1];
  temp:=1;
  WHILE upcase(GO) <> 'B' DO  BEGIN
    window(1,1,80,25);
    menucontrol(wich,go,go2,temp);
    GO:=UPCASE(GO);
(***********************************)
    CASE GO OF
      'S':montecarlo;
      'U':uRANDOM;
      'N':nrandom;
      'G':lotsofbetas;
      'M':multirandom;
    END; (* END OF CASE *)
(************************************************************)
 end;   (* end of while *)
END;       (* end of procedure *)



PROCEDURE dataMENU;
var
    GO,go2:char;
    wich,temp:integer;
begin
  wich:=2;
```

```
(********* CHANGE THESE PARAMETERS TO MAKE A NEW MENU SCREEN *********)
menu^.left[wich]:=18;
menu^.top[wich] :=6;
menu^.max[wich]:=6;
menu^.text[1,wich]:='Enter         ';
menu^.text[2,wich]:='View          ';
menu^.text[3,wich]:='Modify        ';
menu^.text[4,wich]:='Combine       ';
menu^.text[5,wich]:='Average       ';
menu^.text[6,wich]:='Define system ';
menu^.text[0,wich]:='Backup        ';
menu^.text[menu^.max[wich]+1,wich]:='      Data     ';
(**************************************************************************)
go:=menu^.text[1,wich][1];
GO2:=menu^.text[1,wich][1];
temp:=1;
WHILE upcase(GO) <> 'B' DO  BEGIN
  window(1,1,80,25);
  menucontrol(wich,go,go2.temp);
  GO:=UPCASE(GO);
  (**********************************)
  CASE GO OF
   'E':REEDKEY;
   'V':see;
   'M':change;
   'C':combine;
   'A':average;
   'D':entermenu;
 end; (* end of case *)
 (**********************************************************)
end;
end;

PROCEDURE NEWSEED;
begin
setwindow(18,8,43,11);
writeln;
write('New seed: ');intread(seed);
if seed>0 then seed:=seed* -1;
end;


PROCEDURE mainMENU;
var
    GO,go2:char;
    wich,temp:integer;
begin
 (***********************************)
 wich:=1;
 menu^.left[wich]:=1;
 menu^.max[wich]:=6;
 menu^.top[wich]:=3;
 menu^.text[1,wich]:='Data            ';
 menu^.text[2,wich]:='Statistics      ';
 menu^.text[3,wich]:='T-testing       ';
 menu^.text[4,wich]:='Files           ';
 menu^.text[5,wich]:='Random deviates';
 menu^.text[6,wich]:='New seed        ';
 menu^.text[0,wich]:='Quit            ';
 menu^.text[menu^.max[wich]+1,wich]:='   MAIN MENU    ';
 (***********************************)
 go:=menu^.text[1,wich][1];
 GO2:=menu^.text[1,wich][1];
 temp:=1;
 WHILE upcase(GO) <> 'Q' DO  BEGIN
   window(1,1,80,25);
   menucontrol(wich,go,go2,temp);
   GO:=UPCASE(GO);
   (**********************************)
```

```
    CASE GO OF
      'D' : DATAMENU;
      'S' : WORKMENU;
      'T' : TESTMENU;
      'F' : filemenu;
      'N' : NEWSEED;
      'R' : randommenu;
    END; (* END OF CASE AND ELSE*)
    (**********************************)
  end;   (* WHILE LOOP END *)
END;   (* PROCEDURE END *)


procedure open;
type     fyl= file;
var p                                         :pointer;
    x                                         :integer;
    val                                       :real;
    textfil                                   :text;
    fil                                       :fyl;
    result,size                               :word;

  begin
  graphix;
  setcolor(white);
  line(50,100,210,100);
  line(50,100,50,20);
  setcolor(red);
  line(51,60,210,60);
  for x:=1 to 62 do begin
    val:=sin(x/10)/1.5;
    putpixel(51+x,trunc(60-val*50),yellow);
  end;
  for x:=63 to 160 do begin
    val:=sin(x/10)/4;
    putpixel(51+x,trunc(60-val*50),yellow);
  end;
  setcolor(white);
  line(390,100,550,100);
  line(390,100,390,20);
  bar3d(391,100-40,421,99,8,true);
  bar3d(423,100-60,453,99,8,true);
  bar3d(455,100-50,485,99,8,true);
  bar3d(487,100-35,517,99,8,true);
  bar3d(519,100-15,549,99,8,true);
  settextstyle(1,0,5);
  OUTTextxy(60,200,'GENERIC MODEL BUILDER');
  settextstyle(1,0,1);
  outtextxy(280,240,'by 1Lt David Sumner');
  setcolor(white);
  pause:=readkey;
  restorecrtmode;
  end;


 (* MAIN PROGRAM*)
 BEGIN
   open;
   seed:=-12345;
   SETNAME:='NEW';
   sysname:='NEW';
   coloroncolor(white,blue);
   write('                    GENERIC MODEL BUILDER    -- by Dave Sumner                  ');
   gotoxy(1,25);write('                                                                         ');
   coloroncolor(white,black);
   mainMENU;
 END.
```

```
{$R-}    {Range checking off}
{$B+}    {Boolean complete evaluation on}
{$S+}    {Stack checking on}
{$I+}    {I/O checking on}
{$N+}    {8087 required}
{$M 65500,16384,655360} {Turbo 3 default stack and heap}

PROGRAM MATWORKS;
Uses
  Crt,
  Dos,
  PRINTER,
  davemenu;

TYPE
  FILENAME = STRING[12];
  TENBYTEN = ARRAY [1..80,1..80] OF double;
  doubleARR  = ARRAY [1..80] OF double;
  INTARR   = ARRAY [1..80] OF INTEGER;
  WORRD    = STRING[8];
  INFOPTR  = ^INFO;
  INFO     = RECORD
           MATRIX   : TENBYTEN;
           ROWSIZE  : INTEGER;
           COLSIZE  : INTEGER;
           NAME     : WORRD;
           END;

VAR
  MATA,MATB                   :INFOptr;
  pause                       :char;
  ADDSUB                      :INTEGER;
  FIL                         :FILE OF INFO;
  MATNAME                     :WORRD;
  TINY                        :double;
  X,Y,Z                       :INTEGER;
  textfile                    :text;



function power(number,exponent:double):double;
label 10;
begin
if exponent=0 then begin
  power:=1;
  goto 10;end;
if number=0 then begin
  power:=0;
  goto 10;end;
if number > 0.0 then
  power := exp(exponent*ln(number))
else begin
  writeln(number,' number must be positive for power function');
  pause:=readkey;
end;
10:end;



PROCEDURE ludcmp(VAR a:INFOptr; n,np: integer;
       VAR indx: INTARR; VAR d: double);
CONST
   tiny=1.0e-20;
VAR
   k,j,imax,i: integer;
   sum,dum,big: double;
   vv: doubleARR;
```

```
BEGIN
   d := 1.0;
   FOR i := 1 to n DO BEGIN
      big := 0.0;
      FOR j := 1 to n DO IF (abs(a^.MATRIX[i,j]) > big) THEN big := abs(a^.MATRIX[i,j]);
      IF (big = 0.0) THEN BEGIN
         writeln('pause in LUDCMP - singular matrix'); readln
      END;
      vv[i] := 1.0/big
   END;
   FOR j := 1 to n DO BEGIN
      IF (j > 1) THEN BEGIN
         FOR i := 1 to j-1 DO BEGIN
            sum := a^.MATRIX[i,j];
            IF (i > 1) THEN BEGIN
               FOR k := 1 to i-1 DO BEGIN
                  sum := sum-a^.MATRIX[i,k]*a^.MATRIX[k,j]
               END;
               a^.MATRIX[i,j] := sum
            END
         END
      END;
      big := 0.0;
      FOR i := j to n DO BEGIN
         sum := a^.MATRIX[i,j];
         IF (j > 1) THEN BEGIN
            FOR k := 1 to j-1 DO BEGIN
               sum := sum-a^.MATRIX[i,k]*a^.MATRIX[k,j]
            END;
            a^.MATRIX[i,j] := sum
         END;
         dum := vv[i]*abs(sum);
         IF (dum > big) THEN BEGIN
            big := dum;
            imax := i
         END
      END;
      IF (j <> imax) THEN BEGIN
         FOR k := 1 to n DO BEGIN
            dum := a^.MATRIX[imax,k];
            a^.MATRIX[imax,k] := a^.MATRIX[j,k];
            a^.MATRIX[j,k] := dum
         END;
         d := -d;
         vv[imax] := vv[j]
      END;
      indx[j] := imax;
      IF (j <> n) THEN BEGIN
         IF (a^.MATRIX[j,j] = 0.0) THEN a^.MATRIX[j,j] := tiny;
         dum := 1.0/a^.MATRIX[j,j];
         FOR i := j+1 to n DO BEGIN
            a^.MATRIX[i,j] := a^.MATRIX[i,j]*dum
         END
      END
   END;
   IF (a^.MATRIX[n,n] = 0.0) THEN a^.MATRIX[n,n] := tiny
END;


FUNCTION EXIST(temp:WORRD) : BOOLEAN;
VAR FIL:FILE;
    OK :BOOLEAN;
    TEMPP:FILENAME;
GO:CHAR;
BEGIN
  TEMPP:=CONCAT(TEMP,'.MAT');
  ASSIGN(fil,TEMPP);
  {$I-}
```

```
 RESET(FIL);
 {$I+}
 OK:=IORESULT = 0;
 IF NOT OK THEN
   EXIST := FALSE
 ELSE
   BEGIN
   CLOSE(FIL);
   EXIST:=TRUE;
 END;
END;


FUNCTION EXIST2(temp:WORRD) : BOOLEAN;
VAR FIL:FILE;
    OK :BOOLEAN;
    TEMPP:FILENAME;
GO:CHAR;
BEGIN
  TEMPP:=TEMP;
  ASSIGN(FIL,TEMPP);
  {$I-}
  RESET(FIL);
  {$I+}
  OK:=IORESULT = 0;
  IF NOT OK THEN
    EXIST2 := FALSE
  ELSE
    BEGIN
    CLOSE(FIL);
    EXIST2:=TRUE;
  END;
 END;



 PROCEDURE SAVE(MATG:INFOptr;AUTO:INTEGER);
 VAR OVER:CHAR;
     TEMP:FILENAME;
   BEGIN
     over:='y';
     IF AUTO=0 THEN
     BEGIN
     IF EXIST(MATG^.NAME) THEN
       BEGIN
         writeln;WRITE('FILE EXISTS, OVERWRITE?: ');
         OVER:=READKEY;writeln;writeln;
       END;
     END;
     IF UPCASE(OVER) = 'Y' THEN
     BEGIN
       TEMP:=CONCAT(MATG^.NAME,'.MAT');
       ASSIGN(FIL,TEMP);
       REWRITE(FIL);
       WRITE(FIL,MATG^);
       CLOSE(FIL);
     END;
   END;


 PROCEDURE READASCII;
 VAR
    X,Y,Z        :INTEGER;
    FIL          :text;
    GO,NAME      :WORRD;
    mat          :infoptr;
    p            :pointer;
```

```
BEGIN
mark(p);
new(mat);
setwindow(35,10,75,18);
writeln; WRITE('What ASCII file?');
READLN(NAME);
writeln;
IF NOT EXIST2(NAME) THEN
  BEGIN
    WRITEln('FILE DOES NOT EXIST');
    PAUSE:=READKEY;
    release(p);
    EXIT;
  END
ELSE BEGIN
ASSIGN(FIL,NAME);
RESET(FIL);
MATA^.ROWSIZE := 0;
WHILE NOT EOF(FIL) DO
  BEGIN
    MAT^.ROWSIZE := MAT^.ROWSIZE+1;
    MAT^.COLSIZE:=0;
    WHILE NOT EOLN(FIL) DO
      BEGIN
      MAT^.COLSIZE := MAT^.COLSIZE+1;
      READ(FIL,mat^.MATRIX[mat^.ROWSIZE,mat^.COLSIZE]);
      END;
    READLN(FIL);
  END;
CLOSE(FIL);
writeln;WRITE('Name for the MATRIX file?');READLN(mat^.NAME);
SAVE(MAT,0);

END;
release(p);
END;


PROCEDURE READIN(VAR MAT:INFOptr);
VAR GO:CHAR;
    TEMP:FILENAME;
    BEGIN
      if exist(mat^.NAME)
        then
        begin
          TEMP:=CONCAT(mat^.NAME,'.MAT');
          assign(fil,TEMP);
          RESET(FIL);
          READ(FIL,mat^);
          CLOSE(FIL);
        end
        else
          BEGIN
            GOTOXY(17,19);
            write('Sorry, that file is not here ...');
            GO:=READKEY;
          END;
    END;



 FUNCTION LOG(X:double;BASE:double):double;
 BEGIN
 IF (X<0)OR(BASE<2) THEN BEGIN
   WRITE('SORRY, NO NEGATIVE X OR BASE < 2');
   LOG:=1
   END
 ELSE LOG:=LN(X)/LN(BASE);
```

```
END;


PROCEDURE WRITASCII;
VAR
   tempname        :filename;
   max             :double;
   DIG,DEC,X,Y,Z   :INTEGER;
   FIL             :text;
   GO,NAME         :WORRD;
   mata            :infoptr;
   p               : pointer;
BEGIN
mark(p);
new(mata);
setwindow(35,10,75,18);
WRITE('WHICH MATRIX: ');READLN(mata^.NAME);
IF NOT EXIST(mata^.NAME) THEN BEGIN
  writeln;WRITE('FILE DOES NOT EXIST');
  PAUSE:=READKEY;
  release(p);
  EXIT;
END;
READIN(MATA);
write('New data file name? : ');readln(tempname);
ASSIGN(FIL,tempname);
REWRITE(FIL);
(*max:=0;
for x:= 1 to mata^.rowsize do
  for y:= 1 to mata^.colsize do
    if abs(mata^.matrix[x,y])>max then max:=mata^.matrix[x,y];
dig:=trunc(log(max,10))+2;
dec:=10-dig;*)
dec:=0;
dig:=3;
FOR X:= 1 TO mata^.ROWSIZE DO BEGIN
  FOR Y:= 1 TO mata^.COLSIZE DO
    WRITE(FIL,mata^.MATRIX[X,Y]:DIG:DEC);
  WRITELN(FIL);
END;
CLOSE(FIL);
release(p);
END;


procedure onemat(var mata:infoptr);
begin
writeln;
write('Which matrix?: ');readln(mata^.name);
writeln;
end;


PROCEDURE VIEW(MAT:INFOptr;AUTO:INTEGER);
VAR X,Y    :INTEGER;
    saiv   :char;
BEGIN
window(1,1,80,25);
CLRSCR;
FOR X := 1 TO mat^.ROWSIZE DO
  BEGIN
    FOR Y:= 1 TO mat^.COLSIZE DO
      WRITE(mat^.MATRIX[X,Y]:8:4,' ');
    WRITELN;
  END;
PAUSE:=READKEY;
IF AUTO = 0 THEN BEGIN
```

```
  writeln('Do you want to save ',mat^.name,'?  (Y/N)');
  SAIV:=READKEY;
  if upcase(saiv)='Y' then
    save(mat,0);
END;
END;


PROCEDURE REEDKEY;
(* read a matrix in from the keyboard*)
VAR
  X,Y,FYLE : INTEGER;
  OVER     : CHAR;
  mat      :infoptr;
  p        :pointer;
BEGIN
  mark(p);
  new(mat);
  setwindow(35,10,75,18);
  mat^.name:='null';
  mat^.colsize:=1;
  mat^.rowsize:=1;
  WRITE('Name for matrix?: ');
  READLN(mat^.NAME);
  IF EXIST(mat^.NAME) THEN
    BEGIN
    WRITELN;WRITE('FILE EXISTS, OVERWRITE? (Y/N): ');
    OVER := READKEY;
    writeln;
  END
  ELSE
   OVER:='Y';
  IF UPCASE(OVER)='Y' THEN
  BEGIN
    WRITELN;WRITE('How many rows?: ');
    READLN(mat^.ROWSIZE);
    WRITELN; WRITE('How many cols?: ');
    READLN(mat^.COLSIZE);
    FOR X := 1 TO mat^.ROWSIZE DO
      FOR Y := 1 TO mat^.COLSIZE DO
        BEGIN
        WRITELN;WRITE('Enter ELEMENT [',X,',',Y,']: ');
        READLN(mat^.MATRIX[X,Y]);
      END;
  END;
  SAVE(MAT,0);
  release(p);
END;




PROCEDURE CHANGE;
VAR
  X,Y         :INTEGER;
  SAIV,chanj  :CHAR;
  mata        :infoptr;
  p           :pointer;
BEGIN
  mark(p);
  new(mata);
  setwindow(35,10,75,18);
  onemat(mata);
  READIN(MATA);
  IF not EXIST(MATA^.NAME) THEN begin
    release(p);
    exit;
  END;
```

```
CHANJ:='Y';
WHILE CHANJ='Y' DO
BEGIN
      writeln;
      WRITE('Change something? ');
      chanj:=READKEY;
   IF upcase(chanj)='Y' THEN
     BEGIN
       writeln;WRITE('Change which element?(row):');
       READLN(X);
       writeln;WRITE('Change which element?(col):');
       READLN(Y);
       writeln;WRITE('OLD VALUE=',MATa^.MATRIX[X,Y],' NEW=');
       READLN(MATa^.MATRIX[X,Y]);
       writeln;
       view(mata,0)
     END;
   END;
release(p);
END;


PROCEDURE ADDMAT (var MATA,MATB:INFOptr;ADDSUB:INTEGER);
VAR X,Y          :INTEGER;
    SAIV,PAUSE   : CHAR;

BEGIN
  IF (MATA^.ROWSIZE = MATB^.ROWSIZE) AND (MATA^.COLSIZE = MATB^.COLSIZE) THEN
    BEGIN
      WRITE('Name the result: ');
      READLN(MATD^.NAME);
      FOR X := 1 TO MATA^.ROWSIZE DO
        FOR Y := 1 TO MATA^.COLSIZE DO
          MATD^.MATRIX[X,Y] := MATA^.MATRIX[X,Y] + MATB^.MATRIX[X,Y]*ADDSUB;
      VIEW(MATD,0);
    END
  ELSE
    BEGIN
      WRITE('Matrices are not same size ...');
      PAUSE:=READKEY;
    END;
END;


PROCEDURE MULT (MAT1,MAT2:INFOptr; VAR result:INFOptr;AUTO:INTEGER);
VAR X,Y,Z        :INTEGER;
    SUM          :double;
    mat3         :info;
BEGIN
IF (MAT2^.ROWSIZE=MAT1^.COLSIZE) THEN
  BEGIN
  IF AUTO = 0 THEN
    BEGIN
    GOTOXY(30,6); WRITE('MULTIPLY        ');
    GOTOXY(15,19); WRITE('                                          ');
    GOTOXY(15,19); WRITE('What do you want to call the result?:');
    READLN(MAT3.NAME);
    END;
    MAT3.ROWSIZE:=MAT1^.ROWSIZE;
    MAT3.COLSIZE:=MAT2^.COLSIZE;
    FOR X := 1 TO MAT1^.ROWSIZE DO
      FOR Y := 1 TO MAT2^.COLSIZE DO
```

```
        BEGIN
          SUM:=0;
          FOR Z := 1 TO MAT1^.COLSIZE DO
            SUM := SUM + MAT1^.MATRIX[X,Z]*MAT2^.MATRIX[Z,Y];
          MAT3.MATRIX[X,Y]:=SUM;
        END;
    IF AUTO = 0 THEN begin
      result^:=mat3;
      VIEW(result,0);
      save(result,0);
    end;
    result^:=mat3;
  END
  ELSE
    BEGIN
      WRITELN;
      WRITELN('            ',MAT1^.NAME,' X ',MAT2^.NAME,' UNDEFINED DUE TO SIZES.');
      PAUSE:=READKEY;
    END;
END;


PROCEDURE COPY2 (VAR SOURCE:INFOptr); (* ADD A COL OF 1'S TO LEFT OF MATRIX TO GET INTERCEPT *)
VAR X,Y,tempsize : INTEGER;
BEGIN
  source^.colsize := source^.colsize + 1;
  for x:= source^.colsize downto 2 do
    for y:= 1 to source^.rowsize do
      source^.matrix[y,x]:=source^.matrix[y,x-1];
  for x:= 1 to source^.rowsize do
    source^.matrix[x,1]:=1;
END;


PROCEDURE COPY3(VAR SOURCE:INFOptr); (*build x matrix for poly fitting *)
VAR X,Y,Z : INTEGER;

BEGIN
  repeat
    write('To what order?: ');READLN(Z);
    IF Z > SOURCE^.ROWSIZE THEN
      WRITEln('Too few observ''s. Max order = ',SOURCE^.ROWSIZE-2);
  until z<source^.rowsize;
  for x:= 1 to source^.rowsize do
    source^.matrix[x,2]:=source^.matrix[x,1];
  for x:= 1 to source^.rowsize do
    source^.matrix[x,1]:=1;
  for y:= 3 to z do
    for x:= 1 to source^.rowsize do
      source^.matrix[x,y]:=power(source^.matrix[x,2],y-1);
end;


PROCEDURE TRANSPOMAT (var MAT1:INFOptr;auto:integer);
VAR X,Y     :INTEGER;
    SAIV    :CHAR;
    tempval :double;
BEGIN
IF AUTO = 0 THEN
  BEGIN
```

```
    write('name the result :');READLN(MAT1^.NAME);
  END;
  FOR X:= 2 TO MAT1^.ROWSIZE DO
    FOR Y:= 1 TO x-1 DO begin
      tempval:=mat1^.matrix[x,y];
      MAT1^.MATRIX[x,y] := MAT1^.MATRIX[y,X];
      mat1^.matrix[y,x]:=tempval;
    end;
  x:=mat1^.rowsize;
  mat1^.rowsize:=mat1^.colsize;
  mat1^.colsize:=x;
  IF AUTO = 0 THEN begin
    VIEW(MAT1,0);
    save(mat1,0);
  end;
END;



PROCEDURE MANIPMAT(VAR MATA:INFOptr);

VAR  X,Y:INTEGER;
     saiv,CHOICE :  CHAR;
     KONSTANT:double;

BEGIN
  writeln('Name the result?:');READLN(MATa^.NAME);
  writeln('How will you change the matrix?');
  writeln('     1)  square the elements');
  writeln('     2)  square root of the elements');
  writeln('     3)  add a constant to the elements');
  writeln('     4)  multiply by a constant');
  writeln('     5)  divide by a constant');
  writeln;
  CHOICE:=READKEY;
  CASE CHOICE OF
  '1': FOR X := 1 TO mata^.ROWSIZE DO
       FOR Y := 1 TO mata^.COLSIZE DO
         mata^.MATRIX[X,Y]:=  SQR(mata^.MATRIX[X,Y]);
  '2': FOR X := 1 TO mata^.ROWSIZE DO
       FOR Y := 1 TO mata^.COLSIZE DO
         mata^.MATRIX[X,Y] := SQRT(mata^.MATRIX[X,Y]);
  '3': BEGIN
       WRITELN;
       write('Enter your constant:  ');READLN(konstant);
       FOR X := 1 TO mata^.ROWSIZE DO
         FOR Y := 1 TO mata^.COLSIZE DO
           mata^.MATRIX[X,Y] := mata^.MATRIX[X,Y] + konstant;
     end;
  '4': BEGIN
       WRITELN;
       write('Enter your constant:  ');READLN(konstant);
       FOR X := 1 TO mata^.ROWSIZE DO
         FOR Y := 1 TO mata^.COLSIZE DO
           mata^.MATRIX[X,Y] := mata^.MATRIX[X,Y] * konstant;
     end;
  '5': BEGIN
       WRITELN;
       write('Enter your constant:  ');READLN(konstant);
       FOR X := 1 TO mata^.ROWSIZE DO
         FOR Y := 1 TO mata^.COLSIZE DO
           mata^.MATRIX[X,Y] := mata^.MATRIX[X,Y] / konstant;
     end;
 END;
 view(mata,0);
 END;
```

```
PROCEDURE TWOMATS(VAR MATA,MATB:INFOptr);
BEGIN
  writeln;
  WRITE('FIRST MAT:');
  READLN(MATA^.NAME);
  READIN(MATA);
  if not exist(mata^.name) then exit;
  writeln;
  WRITE('SECOND:');
  READLN(MATB^.NAME);
  READIN(MATB);
END;



procedure logit(var mata:infoptr);
var x,y  :integer;
begin
for x:= 1 to mata^.rowsize do
  for y:= 1 to mata^.colsize do
    mata^.matrix[x,y]:=ln(mata^.matrix[x,y]);
end;



PROCEDURE lubksb(a: infoptr; n,np: integer; indx: intarr; VAR b:doublearr);
(* Programs using LUBKSB must define the types
TYPE
   glnarray = ARRAY [1..n] OF real;
   glindx = ARRAY [1..n] OF integer;
   glnpbynp = ARRAY [1..np,1..np] OF real;
in the main routine *)
VAR
   j,ip,ii,i: integer;
   sum: real;
BEGIN
   ii := 0;
   FOR i := 1 to n DO BEGIN
      ip := indx[i];
      sum := b[ip];
      b[ip] := b[i];
      IF  (ii <> 0) THEN BEGIN
         FOR j := ii to i-1 DO BEGIN
            sum := sum-a^.matrix[i,j]*b[j]
         END
      END ELSE IF (sum <> 0.0) THEN BEGIN
         ii := i
      END;
      b[i] := sum
   END;
   FOR i := n DOWNTO 1 DO BEGIN
      sum := b[i];
      IF (i < n) THEN BEGIN
         FOR j := i+1 to n DO BEGIN
            sum := sum-a^.matrix[i,j]*b[j]
         END
      END;
      b[i] := sum/a^.matrix[i,i]
   END
END;



procedure inv(mata:infoptr);
(* takes a matrix inverse, see Press, et al,p.38 *)
var colvect       : doublearr;
    indx          : intarr;
```

```
    D                 : double;
    N,NP,x,y,z,j      : integer;
    tempmat           : info;
begin
  N:= mata^.rowsize;
  NP:=30;
  for x := 1 to N do begin
    for y:= 1 to N do
      tempmat.matrix[x,y]:=0;
    tempmat.matrix[x,x]:=1;
  end;
  ludcmp(mata,N,NP,indx,D);
  for j:= 1 to N do begin
    for y:= 1 to np do colvect[y]:=tempmat.matrix[y,j];
    lubksb(mata,N,NP,indx,colvect);
    for y:= 1 to np do tempmat.matrix[y,j]:=colvect[y];
  end;
  for x:= 1 to N do
    for y:= 1 to N do
      mata^.matrix[x,y]:=tempmat.matrix[x,y];
end;



PROCEDURE DETERMAT(MATG:INFOptr;auto:integer);
VAR X             :INTEGER;
    D             :double;
    INDX          :INTARR;
    good          :boolean;
    math          :infoptr;
    p             :pointer;
BEGIN
    mark(p);
    new(math);
    LUDCMP(MATG,MATG^.ROWSIZE,MATG^.ROWSIZE,INDX,D);
    FOR X := 1 TO MATG^.ROWSIZE DO
      D:=D*MATG^.MATRIX[X,X];
    if auto=1 then begin
      writeln;
      writeln('Determinant = ',d:11:4);
      PAUSE:=READKEY;
    end;
    release(p);
END;


procedure direct;
var tempspec:filename;
begin
setwindow(35,10,75,18);
write('Enter the Filespec : ');readln(tempspec);
window(1,1,80,25);
showdir(tempspec);
end;




PROCEDURE rsm(linsys:integer);
VAR SSR,SST,nybarsq,vary,meany,sumy,SUMYSQ,RSQ,d,sse,ssy    :double;
     logs                            :char;
     good                            :boolean;
     n,k,X,Y                         :INTEGER;
     MATC,MATD                       :INFOPTR;
     yresid,pred                     :doublearr;
     xname,yname                     :worrd;
```

```
    menu                                  :chaR;
    p                                     :pointer;
BEGIN
  mark(p);
  setwindow(19,7,50,16);
  NEW(MATC);NEW(MATD);
  (* read in and work on the x matrix *)
  writeln('X matrix ...');
  ONEMAT(MATA);
  READIN(MATA);
  IF NOT EXIST(MATA^.NAME) THEN begin
    release(p);
    EXIT;
  end;
  if (mata^.rowsize<=mata^.colsize) then begin
    writeln('Too few observations ...');
    pause:=readkey;
    release(p);
    exit
  end;
  n:=mata^.rowsize;
  write('Natural logarithms of X? : ');
  LOGS:=READKEY;
  writeln;
  if ('logs='y') or ('logs='Y') then
    logit(mata);
  coPY2(MATa);                    (* add constant column of ones *)
  k:=mata^.colsize;
  view(mata,0);
  matb^:=mata^;
  matd^:=mata^;
  TRANSPOMAT(MATB,1);             (* matb returns xt *)
  MULT(MATB,MATA,MATa,1);         (* mata^ returns xtx *)
  INV(MATa);                      (* mata returns xtx inv *)
  (* now read in and work on the y matrix *)
  writeln;
  writeln('Y matrix ...');
  ONEMAT(MATC);
  READIN(MATC);
  IF NOT EXIST(MATC^.NAME) THEN begin
    release(p);
    EXIT;
  end;
  yname:=matc^.name;
  write('Natural logarithms of Y? : ');LOGS:=READKEY;
  writeln;
  if (logs='y') or (logs='Y') then logit(matc);
  for x:= 1 to matc^.rowsize do
    yresid[x]:=matc^.matrix[x,1];
  MULT(MATB,MATC,MATb,1);              (* matd^ returns xty          *)
  MULT(MATA,MATb,MATc,1);              (* matc returns estimated β's *)
  view(matc,0);
  (* find mean and sum of sq of y *)
  sumy:=0;
  sumysq:=0;
  for x:= 1 to n do begin
    sumy:= sumy+yresid[x];
    sumysq:=sumysq+sqr(yresid[x]);
  end;
  meany:= (sumy/n);

  (* calclulate the yhat vector *)
  (* note: here resid^ holds the x matrix *)
  mult(matd,matc,matd,1);              (* matd^ returns yhat *)
  view(matd,0);
  for x:= 1 to n do
    pred[x]:=matd^.matrix[x,1];
  (* calculate the residual vector *)
  for x:= 1 to matd^.rowsize do
```

```
    yresid[x]:=yresid[x]-pred[x];
  (* calculate n*sqr(y mean)  *)
  nybarsq:=matd^.rowsize*sqr(meany);
  (* calculate the sum of residuals squared *)
  sse:=0;
  for x:= 1 to n do
    sse:=sse + sqr(yresid[x]);
  transpomat(matc,1); (* transpose the beta hat vector *)
  mult(matc,matb,matb,1);(* matb returns b'x'y *)
  SSR:=matb^.matrix[1,1]-nybarsq;
  SST:=sumysq-nybarsq;
  writeln('β covariance matrix ...');
  for x:= 1 to mata^.rowsize do
    for y:= 1 to mata^.colsize do
      mata^.matrix[x,y]:=mata^.matrix[x,y]*(sse/(n-k));
  window(1,1,80,25);clrscr;
  writeln('  Estimator       Estimate      Std Error         T value');
  writeln('[redacted]');
  writeln;
  for x:= 1 to matc^.colsize do begin
    writeln('        β',x-1,'      ',matc^.matrix[1,x]:11:5,'     ',sqrt(mata^.matrix[x,x]):11:5,
        '      ',matc^.matrix[1,x]/sqrt(mata^.matrix[x,x]):11:5);
  end;
  writeln;
  writeln('N       =  ',n);
  writeln('R²      = ',SSR/SST:8:5);
  writeln('MSE     = ',sse/(n-k));
  writeln;
  writeln('     P) Predictions and residuals');
  writeln('     B) Beta covariance matrix   ');
  writeln('     M) Menu                     ');
  menu:=readkey;
  if upcase(menu)='P' then begin
    clrscr;
    writeln('Predictions       Residuals');
    writeln('[redacted]');
    for x:= 1 to n do
      writeln(pred[x]:11:5,'      ',yresid[x]:11:5);
    PAUSE:=READKEY;
  end
  else if upcase(menu)='B' then begin
    for x:= 1 to mata^.rowsize do begin
      writeln;
      for y:= 1 to mata^.colsize do
        write(mata^.matrix[x,y]:11:5);
    end;
    pause:=readkey;
  end;
  release(p);
end;
```

```
PROCEDURE xtransform(linsys:integer);
VAR SSR,SST,nybarsq,vary,meany          :double;
    sumy,SUMYSQ,RSQ,d,sse,ssy,old      :double;
    logs                               :char;
    good                               :boolean;
    pass,n,k,numx,X,Y                  :INTEGER;
    MATC,MATD                          :INFOPTR;
    yresid,pred,yvect                  :doublearr;
    xname,yname                        :worrd;
    menu                               :chaR;
    p                                  :pointer;
```

```
    alphasig                          :boolean;
    alpha                             :doublearr;
BEGIN
  mark(p);
  pass:=1;
  setwindow(19,7,50,16);
  NEW(MATC);NEW(MATD);
  (* read in and work on the x matrix *)
  writeln('X matrix ...');
  ONEMAT(MATA);
  xname:=mata^.name;
  READIN(MATA);
  IF NOT EXIST(MATA^.NAME) THEN begin
    release(p);
    EXIT;
  end;
  if (mata^.rowsize<=mata^.colsize) then begin
    writeln('Too few observations ...');
    pause:=readkey;
    release(p);
    exit
  end;
  n:=mata^.rowsize;
  numx:=mata^.colsize;
  copy2(mata);
  for x:= 1 to n do
    alpha[x]:=1;
  writeln;
  writeln('Y matrix ...');
  ONEMAT(MATC);
  READIN(MATC);
  IF NOT EXIST(MATC^.NAME) THEN begin
    release(p);
    EXIT;
  end;
  yname:=matc^.name;
  FOR X:= 1 TO MATC^.ROWSIZE DO
    YVECT[X]:=MATC^.MATRIX[X,1];
  write('Natural logarithms of Y? : ');LOGS:=READKEY;
  writeln;
  if (logs='y') or (logs='Y') then logit(matc);

  repeat

    matd^:=mata^;
    matb^:=mata^;
    TRANSPOMAT(MATB,1);              (* matb returns xt *)
    MULT(MATB,MATA,MATa,1);            (* mata^ returns xtx *)
    INV(MATA);
    (* now work on the y matrix *)
    MULT(MATB,MATC,MATB,1);           (* matB^ returns xty          *)
    MULT(MATA,MATB,MATC,1);            (* matC returns estimated β's *)
    writeln('Pass = ',pass);
    (* find mean and sum of sq of y *)
    sumy:=0;
    sumysq:=0;
    for x:= 1 to matc^.rowsize do begin
      sumy:= sumy+matc^.matrix[x,1];
      sumysq:=sumysq+sqr(matc^.matrix[x,1]);
    end;
    meany:= (sumy/x);
    (* calclulate the yhat vector *)
    (* note: here MATD holdS the x matrix *)
    mult(MATD,MATC,MATD,1);
    (* calculate the residual vector *)
    for x:= 1 to matD^.rowsize do
      YreSId[x]:=YVECT[X]-matD^.matrix[x,1];
    (* calculate n*sqr(y mean)  *)
    nybarsq:=n*sqr(meany);
```

```
(* calculate the sum of residuals squared *)
sse:=0;
for x:= 1 to MATD^.rowsize do
  sse:=sse + sqr(YRESID[x]);
transpomat(matC,1); (* transpose the beta hat vector *)
mult(matC,matB,matB,1);


SSR:=matB^.matrix[1,1]-nybarsq;
SST:=sumysq-nybarsq;
for x:= 1 to mata^.rowsize do
  for y:= 1 to mata^.colsize do
    mata^.matrix[x,y]:=mata^.matrix[x,y]*(sse/(n-numx-1));



(* now create the Z values *)
MATA^.NAME:=XNAME;
READIN(MATA);
for x:= 1 to n do
  for y:= 1 to numx do
    mata^.matrix[x,y]:=power(mata^.matrix[x,y],alpha[y]);
for x:= 1 to matA^.rowsize do
  for y:= 1 to matA^.colsize do
    matA^.matrix[x,y+numx]:=matC^.matrix[1,y+1]*matA^.matrix[x,y]*LN(matA^.matrix[x,y]);
(* now regress again, this time on X|Z *)
mata^.colsize:=numx * 2;
copy2(mata);
MATB^:=MATA^;
MATD^:=MATA^;
k:=matA^.colsize;
TRANSPOMAT(MATB,1);               (* matb returns xt      *)
MULT(MATB,MATA,matA,1);           (* matA returns xtx     *)
INV(matA);                        (* matA returns xtx inv *)
(* now work on the y matrix *)
matc^.name:=yname;
readin(matc);
MULT(MATB,MATC,MATB,1);              (* matB^ returns xty          *)
MULT(MATA,MATB,MATC,1);              (* matC returns estimated β's *)
(* note: on next  line matd will hold the x matrix *)
mult(MATD,matC,MATD,1);              (* calclulate the yhat vector, put it in matd *)
FOR X:= 1 TO n DO
  PRED[X]:=MATD^.MATRIX[X,1];
(* calculate the residual vector *)
for x:= 1 to n do
  YRESID[x]:=YVECT[X]-pred[x];
(* calculate the sum of residuals squared *)
sse:=0;
for x:= 1 to n do
  sse:=sse + sqr(YRESID[x]);
transpomat(matC,1); (* transpose the beta hat vector *)
mult(matC,matB,matB,1);
SSR:=matB^.matrix[1,1]-nybarsq;
SST:=sumysq-nybarsq;
for x:= 1 to mata^.rowsize do (* modify xtxinv to be var-cov matrix *)
  for y:= 1 to matA^.colsize do
    matA^.matrix[x,y]:=matA^.matrix[x,y]*(sse/(n-(numx*2+1)));
alphasig:=false;
(* test to see if any alphas are significant *)
for x:= 1 to numx do
  if abs(matC^.matrix[1,x+numx+1]) > abs(2*sqrt(matA^.matrix[x+numx+1,x+numx+1])) then begin
    alpha[x]:=alpha[x]*(matC^.matrix[1,x+numx+1]+1);
    alphasig:=true;
  end;
mata^.name:=xname;        (* recall the name of the original x matrix *)
if alphasig then begin  (* transformation for subsequent passes if any significant    *)
  readin(mata);
  for x:= 1 to mata^.rowsize do
    for y:=1 to mata^.colsize do
```

```
          mata^.matrix[x,y]:=power(mata^.matrix[x,y],alpha[y]);
      copy2(mata);
      matc^.rowsize:=n;
      matc^.colsize:=1;
      for x:= 1 to n do
        matc^.matrix[x,1]:=yvect[x];
    end;
    (* show betas and cov matrix if nothing significant on first pass *)
    if not(alphasig) and (pass=1) then begin
      writeln('pass = ',pass);
      for x:=1 to numx*2+1 do
        writeln(matc^.matrix[1,x]:11:5,'   ',sqrt(matA^.matrix[x,x]):11:5);
      pause:=readkey;
    end;
    pass:=pass+1;

  until not(alphasig);

  window(1,1,80,25);clrscr;
  writeln('  Estimator       Estimate   ');
  writeln('[redacted]');
  writeln;
  for x:=  1 to numx do
    writeln('      α',x,'        ',alpha[x]:11:5);
  writeln;
  writeln('Perform the transformations? :');pause:=readkey;
  writeln;
  if (pause='y') or (pause='Y') then begin
    mata^.name:=xname;        (* recall the name of the original x matrix *)
    readin(mata);
    writeln('Name for transformed matrix : ');readln(mata^.name);
    for x:= 1 to mata^.rowsize do
      for y:=1 to mata^.colsize do
        mata^.matrix[x,y]:=power(mata^.matrix[x,y],alpha[y]);
    save(mata,1);
  end;
  release(p);
end;




PROCEDURE datamenu;
var
    GO,go2:char;
    wich,temp:integer;
begin
  (**********************************)
  wich:=3;
  menu^.left[wich]:=18;
  menu^.max[wich]:=7;
  menu^.top[wich]:=6;
  menu^.text[1,wich]:='Enter          ';
  menu^.text[2,wich]:='View           ';
  menu^.text[3,wich]:='Import ASCII   ';
  menu^.text[4,wich]:='Write ASCII    ';
  menu^.text[5,wich]:='Disk Dir       ';
  menu^.text[6,wich]:='List MAT files';
  menu^.text[7,wich]:='Modify         ';
  menu^.text[0,wich]:='Backup         ';
  menu^.text[menu^.max[wich]+1,wich]:='   DATA MENU   ';
  (************************************)
  go:=menu^.text[1,wich][1];
  GO2:=menu^.text[1,wich][1];
  temp:=1;
```

```
WHILE upcase(GO) <> 'B' DO  BEGIN
  window(1,1,80,25);
  menucontrol(wich,go,go2,temp);

  GO:=UPCASE(GO);
  (**********************************)
  CASE GO OF
    'E':REEDKEY;
    'V':BEGIN
          setwindow(35,10,75,18);
          onemat(mata);
          READIN(MATA);
          IF EXIST(MATA^.NAME)THEN
            VIEW(MATA,0);
        END;
    'I':READASCII;
    'W':WRITASCII;
    'L':SHOWDIR('*.MAT');
    'D':direct;
    'M':BEGIN
          setwindow(35,10,75,18);
          onemat(mata);
          READIN(MATA);
          IF EXIST(MATA^.NAME) THEN
            CHANGE;
        END;

  end;
end;
END;



PROCEDURE workmenu;
var
    GO,go2:char;
    wich,temp:integer;
    sing        :boolean;
    indx        : INTARR;
    d           : double;
    good        :boolean;
BEGIN
  (**********************************)
  wich:=2;
  menu^.left[wich]:=18;
  menu^.max[wich]:=7;
  menu^.top[wich]:=6;
  menu^.text[1,wich]:='Add            ';
  menu^.text[2,wich]:='Subtract       ';
  menu^.text[3,wich]:='Multiply       ';
  menu^.text[4,wich]:='Invert         ';
  menu^.text[5,wich]:='Transpose      ';
  menu^.text[6,wich]:='Change Matrix  ';
  menu^.text[7,wich]:='Determinant    ';
  menu^.text[0,wich]:='Backup         ';
  menu^.text[menu^.max[wich]+1,wich]:='  MATRIX MENU  ';
  (**********************************)
  go:=menu^.text[1,wich][1];
  GO2:=menu^.text[1,wich][1];
  temp:=1;
  WHILE upcase(GO) <> 'B' DO  BEGIN
    window(1,1,80,25);
    menucontrol(wich,go,go2,temp);

    GO:=UPCASE(GO);

    (**********************************)
    CASE GO OF
```

```
'A':BEGIN
  SETWINDOW(35,9,79,18);
      TWOMATS(MATA,MATB);
      IF EXIST(MATA^.NAME) AND EXIST(MATB^.NAME) THEN
        ADDMAT(MATA,MATB,1);
   END;
'S':  BEGIN
    SETWINDOW(35,9,79,18);
      TWOMATS(MATA,MATB);
      IF EXIST(MATA^.NAME) AND EXIST(MATB^.NAME) THEN
      ADDMAT(MATA,MATB,-1);
    END;
'M':  BEGIN
      SETWINDOW(35,9,79,18);
      TWOMATS(MATA,MATB);
      IF EXIST(MATA^.NAME) AND EXIST(MATB^.NAME) THEN
      MULT(MATA,MATB,MATD,0);
    END;
'I':BEGIN
      SETWINDOW(35,9,79,18);
      onemat(mata);
      READIN(MATA);
      IF EXIST(MATA^.NAME) THEN begin
        INV(MATA);
        WRITE('NAME THE INVERSE: ');READLN(MATa^.NAME);
        VIEW(MATa,0);
      end;
    END;
'T':BEGIN
      SETWINDOW(35,9,79,18);
      onemat(mata);
      READIN(MATA);
      IF EXIST(MATA^.NAME) THEN
      TRANSPOMAT(MATA,0);
    END;
'C':BEGIN
      SETWINDOW(35,9,79,18);
      onemat(mata);
      READIN(MATA);
      IF EXIST(MATA^.NAME) THEN
        MANIPMAT(MATA);
    end;
'D':BEGIN
      SETWINDOW(35,9,79,18);
      onemat(mata);
      READIN(MATA);
      IF EXIST(MATA^.NAME) THEN
        DETERMAT(MATA,1);
    end;
   END; (* END OF CASE AND ELSE*)
   (**********************************)
  end;   (* WHILE LOOP END *)
END;   (* PROCEDURE END *)



PROCEDURE mainMENU;
var
    GO,go2:char;
    wich,temp:integer;
begin
  (************************************)
  wich:=1;
  menu^.left[wich]:=1;
  menu^.max[wich]:=4;
  menu^.top[wich]:=3;
  menu^.text[1,wich]:='Data           ';
```

```
 menu^.text[2,wich]:='Matrix ops     ';
 menu^.text[3,wich]:='Regression     ';
 menu^.text[4,wich]:='X transform    ';
 menu^.text[0,wich]:='Quit';
 menu^.text[menu^.max[wich]+1,wich]:='    MAIN MENU    ';
 (***********************************)
 go:=menu^.text[1,wich][1];
 GO2:=menu^.text[1,wich][1];
 temp:=1;
 WHILE upcase(GO) <> 'Q' DO  BEGIN
   windo=(1,1,80,25);
   menucontrol(wich,go,go2,temp);

   GO:=UPCASE(GO);
   (**********************************)
   CASE GO OF
     'D' : DATAMENU;
     'M' : WORKMENU;
     'R' : rsm(0);
     'X' : xtransform(0);
   END; (* END OF CASE AND ELSE*)
   (**********************************)
  end;   (* WHILE LOOP END *)
END;   (* PROCEDURE END *)


(* MAIN PROGRAM*)
BEGIN
new(mata);new(matb);
TINY:=0.000001;
clrscr;
textbackground(blue);
write(                              MATRIX  -- by Dave Sumner                              ');
gotoxy(1,25);write('                                                                                ');
TEXTBACKGROUND(BLACK);
MAINMENU;
END.
```

```
unit davestat;

(**********************************************************************
  This unit contains many of the statistical procedures called in the
  probstat program.  Some of them are original, and others are taken from
  Numerical Recipes or Turbo Pascal Programmer's Library.
 **********************************************************************)


INTERFACE
uses crt,davemenu;


TYPE
  vect        = array[0..20] of integer;
  largevect   = array[1..100]of double;
  doubvect    = array[0..10] of double;
  twenvect    = array[0..20] of double;
  charvect    = array[1..20] of char;
  threebytwen= array[1..3,0..20] of double;
  fourbytwen = array[1..4,0..20]of double;
  tensq       = array[1..10,1..10] of double;
  twensq      = array[1..20,1..20] of double;
  twencube    = array[1..20,1..10,1..10] of double;
  fourtwensq = array[0..20,0..20,1..4] of double;

  systemrec  = record              (* Holds the system cost definitions     *)
        vars         : threebytwen; (* Single var type,hi,low                *)
        varstime     : fourbytwen;  (* Single var nocost,PI,CON,PO lengths   *)
        cervars      : fourtwensq;  (* Cer explanatory var type,hi,low,alpha *)
        certime      : fourbytwen;  (* Cer nocost,PI,CON,PO lengths          *)
        cerbetas     : twensq;      (* Cer beta estimates                    *)
        certypes     : charvect;    (* Cer type                              *)
        cermse       : twenvect;    (* Cer MSE                               *)
        cercovs      : twencube;    (* Cer cov matrices (cholesky sqrt)      *)
        rate         : double;      (* Associated interest rate for PV       *)

     end;

  sysptr = ^systemrec;
  AXISANNSIZE = STRING[80];
  ANNARRAYTYPE = ARRAY [0..21] OF AXISANNSIZE;
  FILENAME = STRING[12];
  WORRD     = STRING[8];
  infomatptr  = ^info;
  INFOmat      = RECORD
          MATRIX   : tensq;
          ROWSIZE  : INTEGER;
          COLSIZE  : INTEGER;
          NAME     : WORRD;
          END;

  DATARAY   = ARRAY [1..2500] OF double;
  INFO      = RECORD
          DATA     : DATARAY;
          SIZE     : INTEGER;
          NAME     : WORRD;
  END;
  infoptr   = ^info;


 CONST
   XORI=1;
   YORI=12;

 var

   FIL                                    :FILE OF INFO;
   sysname,setname                        :WORRD;
```

```
MAT1,MAT2,mat3                            :INFOmat;
pause                                     :char;
sys                                       :sysptr;
seed                                      :integer;

 x,y,z,count,glix1,glix2,glix3,seed1,seed2: integer;
 glr                                      : ARRAY [1..97] OF double;
 glinext,glinextp                         : integer;
 glma                                     : ARRAY [1..55] OF double;

FUNCTION ran3(VAR idum: integer): double; (* from numerical recipes *)
PROCEDURE MEANVAR(SETG:INFO;VAR MEAN,VARIANCE:double); (* original *)
PROCEDURE JACK(SETG:INFO;VAR ZMEAN,ZVAR:double); (* original *)
FUNCTION gammln(xx: double): double;
FUNCTION betai(a,b,x: double): double;
function tvalue(tstat:double;df:integer):double;
function fvalue(fstat:double;df1,df2:integer):double;
FUNCTION EXIST(temp:WORRD) : BOOLEAN;

FUNCTION EXIST2(temp:filename) : BOOLEAN;
PROCEDURE SAVE(SETg:INFO);
PROCEDURE READIN(VAR SETG:INFO);
PROCEDURE TWOSETS(VAR SETA,SETB:INFO);
PROCEDURE MULTmat;
PROCEDURE READASCII;
PROCEDURE WRITASCII;
PROCEDURE REEDKEY;
PROCEDURE CHANGE;
PROCEDURE SEE;
PROCEDURE SORTHR (VAR SETG:INFO);
PROCEDURE QUANTILES;
PROCEDURE PROBABILITY;


IMPLEMENTATION


FUNCTION ran3(VAR idum: integer): double; (* from numerical recipes *)

(**********************************************************************
This procedure was taken from Numerical recipes.  It generates uniform(0,1)
variables.
**********************************************************************)

(* Programs using RAN3 must declare the following variables
in the main routine. Machines with 4-byte integers can use the integer
implementation of this routine, substituting glma of type integer, the
commented CONST and VAR declarations, and the MOD function in the third
line after the BEGIN. *)
(* CONST
   mbig=1000000000;
   mseed=161803398;
   mz=0;
   fac=1.0e-9;
VAR
   i,ii,k,mj,mk: integer; *)
CONST
   mbig=4.0e6;
   mseed=1618033.0;
   mz=0.0;
   fac=2.5e-7; (* 1/mbig *)
VAR
   i,ii,k: integer;
   mj,mk: double;
BEGIN
   IF (idum < 0) THEN BEGIN
      mj := mseed+idum;
```

```
      (* The following IF block is mj := mj MOD mbig; for real variables. *)
      IF mj>=0.0 THEN mj := mj-mbig*trunc(mj/mbig)
         ELSE mj := mbig-abs(mj)+mbig*trunc(abs(mj)/mbig);
      glma[55] := mj;
      mk := 1;
      FOR i := 1 to 54 DO BEGIN
         ii := 21*i MOD 55;
         glma[ii] := mk;
         mk := mj-mk;
         IF (mk < mz) THEN mk := mk+mbig;
         mj := glma[ii]
      END;
      FOR k := 1 to 4 DO BEGIN
         FOR i := 1 to 55 DO BEGIN
            glma[i] := glma[i]-glma[1+((i+30) MOD 55)];
            IF (glma[i] < mz) THEN glma[i] := glma[i]+mbig
         END
      END;
      glinext := 0;
      glinextp := 31;
      idum := 1
   END;
   glinext := glinext+1;
   IF (glinext = 56) THEN glinext := 1;
   glinextp := glinextp+1;
   IF (glinextp = 56) THEN glinextp := 1;
   mj := glma[glinext]-glma[glinextp];
   IF (mj < mz) THEN mj := mj+mbig;
   glma[glinext] := mj;
   ran3 := mj*fac;
END;


PROCEDURE MEANVAR(SETG:INFO;VAR MEAN,VARIANCE:double); (* original *)

(***********************************************************************
This procedure is all original.  It calculates the mean and variance of
a data set using n-1 weighting.
***********************************************************************)

VAR SUM,SUMSQ:double;
    X:INTEGER;
BEGIN
  IF SETG.SIZE<=2 THEN EXIT;
  SUMSQ :=0;
  SUM   :=0;
  FOR X := 1 TO SETG.SIZE DO
    BEGIN
      SUMSQ := SUMSQ + SQR(SETG.DATA[X]);
      SUM   := SUM + SETG.DATA[X];
    END;
  MEAN      := SUM/X;
  VARIANCE  := (SUMSQ - x*SQR(mean))/(X-1);
END;


PROCEDURE JACK(SETG:INFO;VAR ZMEAN,ZVAR:double); (* original *)

(***********************************************************************
This procedure calcualtes the "jacknife" estimate of the sample variance.
The standard error of this estimate allows a confidence interval (symmetric)
to be drawn on the sample variance.
***********************************************************************)

VAR PSUEDOJ                                       :DATARAY;
    SUMZ,SUMZSQ,SUM,SUMSQ,MEAN,MEANJ,VARIANCE :double;
    X,Y,M                                         :INTEGER;
```

```
(****************************************************************************
In calculating the pseudovalues and z values, it is necessary to sum
the entire sample set and their squares n times, each  time leaving out
the i'th value.  This procedure gets around that.  First the entire set
and their squares are summed.  Then, the first value is subracted from the
sum, and its square from the sum of squares, and the appropriate psuedovalue
and z value are generated.  Then the value is added back in and the next
value is subtracted out.

****************************************************************************)

BEGIN
  IF SETG.SIZE<=2 THEN EXIT;
  MEANVAR(SETG,MEAN,VARIANCE);
  M      :=SETG.SIZE;
  SUMZ   :=0;
  SUMZSQ :=0;
  SUM    :=0;
  SUMSQ  :=0;
  FOR X := 1 TO SETG.SIZE DO
    BEGIN
    SUMSQ := SUMSQ + SQR(SETG.DATA[X]);
    SUM   := SUM + SETG.DATA[X];
    END;
  FOR Y:= 1 TO SETG.SIZE DO
    BEGIN
    SUM        :=SUM-SETG.DATA[Y];
    SUMSQ      :=SUMSQ-SQR(SETG.DATA[Y]);
    MEANJ      := SUM/(M-1);
    psuedoj[y]:= (SUMSQ - (M-1)*SQR(meanJ))/(M-2);
    PSUEDOJ[Y]:= M*(VARIANCE)-(M-1)*psuedoj[Y];
    SUMZ       :=SUMZ+PSUEDOJ[Y];
    SUMZSQ     :=SUMZSQ+SQR(PSUEDOJ[Y]);
    SUM        :=SUM+SETG.DATA[Y];
    SUMSQ      :=SUMSQ+SQR(SETG.DATA[Y]);
    END;
  ZMEAN :=SUMZ/Y;
  ZVAR  :=(SUMZSQ-(M*SQR(ZMEAN)))/(M-1);
END;


FUNCTION gammln(xx: double): double;

(****************************************************************************
This is an incomplete gamma function pulled from Numerical Recipes.  It is
used to find T values and F values.
****************************************************************************)

CONST
   stp = 2.50662827465;
   half = 0.5;
   one = 1.0;
   fpf = 5.5;
VAR
   x,tmp,ser: double;
   j: integer;
   cof: ARRAY [1..6] OF double;
BEGIN
   cof[1] := 76.18009173;
   cof[2] := -86.50532033;
   cof[3] := 24.01409822;
   cof[4] := -1.231739516;
   cof[5] := 0.120858003e-2;
   cof[6] := -0.536382e-5;
   x := xx-one;
   tmp := x+fpf;
   tmp := (x+half)*ln(tmp)-tmp;
   ser := one;
   FOR j := 1 to 6 DO BEGIN
```

```
      x := x+one;
      ser := ser+cof[j]/x
   END;
   gammln := (tmp+ln(stp*ser))
END;
FUNCTION betacf(a,b,x: double): double;
LABEL 1;
CONST
   itmax=100;
   eps=3.0e-7;
VAR
   tem,qap,qam,qab,em,d: double;
   bz,bpp,bp,bm,az,app: double;
   am,aold,ap: double;
   m: integer;
BEGIN
   am := 1.0;
   bm := 1.0;
   az := 1.0;
   qab := a+b;
   qap := a+1.0;
   qam := a-1.0;
   bz := 1.0-qab*x/qap;
   FOR m := 1 to itmax DO BEGIN
      em := m;
      tem := em+em;
      d := em*(b-m)*x/((qam+tem)*(a+tem));
      ap := az+d*am;
      bp := bz+d*bm;
      d := -(a+em)*(qab+em)*x/((a+tem)*(qap+tem));
      app := ap+d*az;
      bpp := bp+d*bz;
      aold := az;
      am := ap/bpp;
      bm := bp/bpp;
      az := app/bpp;
      bz := 1.0;
      IF ((abs(az-aold)) < (eps*abs(az))) THEN GOTO 1
   END;
   writeln('pause in BETACF');
   writeln('a or b too big, or itmax too small'); readln;
1:  betacf := az
END;


FUNCTION betai(a,b,x: double): double;
(*************************************************************************
This is an incomplete beta function used to generate T and Z values.  See
Numerical Recipes.
*************************************************************************)
VAR
   bt: double;
BEGIN
   IF ((x < 0.0) OR (x > 1.0)) THEN BEGIN
      writeln('pause in routine BETAI'); readln
   END;
   IF ((x = 0.0) OR (x = 1.0)) THEN bt := 0.0
   ELSE bt := exp(gammln(a+b)-gammln(a)-gammln(b)
          +a*ln(x)+b*ln(1.0-x));
   IF (x < ((a+1.0)/(a+b+2.0))) THEN
      betai := bt*betacf(a,b,x)/a
   ELSE betai := 1.0-bt*betacf(b,a,1.0-x)/b
END;


function tvalue(tstat:double;df:integer):double;

(*************************************************************************
This is original, using a formula developed in Numerical Recipes.
```

```
note: this returns the p value of t statistic and df, for one
tailed test.
************************************************************************)

begin
tvalue:=betai(df/2,1/2,df/(df+tstat*tstat))/2;
end;


function fvalue(fstat:double;df1,df2:integer):double;

(************************************************************************
This returns the p value for fstat and the two degrees of freedom.
************************************************************************)

begin
fvalue:=betai(df2/2,df1/2,df2/(df2+df1*fstat));
end;


FUNCTION EXIST(temp:WORRD) : BOOLEAN;
(* this checks to se if the given ".set" file is on the disk *)
var
    OK      :BOOLEAN;
    TEMPP   :FILENAME;
    GO      :CHAR;
BEGIN
  TEMPP:=CONCAT(TEMP, '.SET');
  ASSIGN(fil,TEMPP);
  {$I-}
  RESET(FIL);
  {$I+}
  OK:=IORESULT = 0;
  IF NOT OK THEN
    EXIST := FALSE
  ELSE
    BEGIN
    CLOSE(FIL);
    EXIST:=TRUE;
  END;
END;


FUNCTION EXIST2(temp:filename) : BOOLEAN;
(* this checks to see if the file name passed in is on the disk *)
VAR FIL     :FILE;
    OK      :BOOLEAN;
    TEMPP   :FILENAME;
GO:CHAR;
BEGIN
  TEMPP:=TEMP;
  ASSIGN(fil,TEMPP);
  {$I-}
  RESET(FIL);
  {$I+}
  OK:=IORESULT = 0;
  IF NOT OK THEN
    EXIST2 := FALSE
  ELSE
    BEGIN
    CLOSE(FIL);
    EXIST2:=TRUE;
```

```
  END;
END;


PROCEDURE SAVE(SETg:INFO);
(* this procedure writes the data set to a '.set' disk file *)
VAR OVER    :CHAR;
    TEMP    :FILENAME;
label 10;
BEGIN
10: TEMP:=CONCAT(SETG.NAME,'.SET');
    IF EXIST(SETG.NAME) THEN
      BEGIN
        WRITE('File Exists, Overwrite?: ');
        OVER:=READKEY;
        writeln;
      END
    ELSE
      OVER:='Y';
    IF UPCASE(OVER) = 'Y' THEN
    BEGIN
      ASSIGN(FIL,TEMP);
      REWRITE(FIL);
      WRITE(FIL,SETg);
      CLOSE(FIL);
    END
    ELSE begin
      WRITE('New name ("q" to quit): ');
      readln(setg.name);
      if (setg.name='q') or (setg.name='Q') then exit;
      setname:=setg.name;
      goto 10;
    end;
END;


PROCEDURE READIN(VAR SETG:INFO);
(* this procedure reads a ".set" file from disk into the SETG variable *)
VAR PAUSE       :CHAR;
    TEMP        :FILENAME;
    TEMPNAME    :WORRD;
    BEGIN
      writeln;
      WRITE('Data file name? (',SETNAME,'): ');READLN(TEMPNAME);
      IF TEMPNAME <> '' THEN
        SETNAME:=TEMPNAME;
      SETG.NAME:=SETNAME;
      if exist(setg.name) then begin
        TEMP:=CONCAT(SETG.NAME,'.SET');
        ASSIGN(FIL,TEMP);
        RESET(FIL);
        READ(FIL,SETG);
        CLOSE(FIL);
      end
      else BEGIN
        writeln;
        write('Data file does not exist ...');
        PAUSE:=READKEY;
      END;
    END;


(* original *)
PROCEDURE TWOSETS(VAR SETA,SETB:INFO);
(* this provideds the prompts for reading two '.set' data files from disk *)
BEGIN
  setwindow(36,10,78,18);
```

```
  writeln;
  WRITEln('FIRST SET: ');
  writeln('*********');
  READIN(SETA);
  writeln;
  writeln;
  WRITEln('SECOND SET:');
  writeln('**********');
  READIN(SETB);
  writeln;
END;



PROCEDURE MULTmat;
(* this procedure multiplies matrices, it is used by the MULTINORMAL      *)
(* variate generator, which is used to sample dependent β parameters      *)
(***** note that it uses the matrices that are global variables to avoid *)
(*****    passing parameters and filling up the stack.                    *)
VAR X,Y,Z       :INTEGER;
    SUM         :double;
BEGIN
    MAT3.ROWSIZE:=MAT1.ROWSIZE;
    MAT3.COLSIZE:=MAT2.COLSIZE;
    FOR X := 1 TO MAT1.ROWSIZE DO
      FOR Y := 1 TO MAT2.COLSIZE DO BEGIN
        SUM:=0;
        FOR Z := 1 TO MAT1.COLSIZE DO
          SUM := SUM + MAT1.MATRIX[X,Z]*MAT2.MATRIX[Z,Y];
        MAT3.MATRIX[X,Y]:=SUM;
      END;
end;

PROCEDURE READASCII;
(* this reads a single column ascii file and stores data in a ".set" file *)
TYPE
  FYL = TEXT;
VAR
   X,Y,Z      :INTEGER;
   FIL        :FYL;
   GO,NAME    :WORRD;
   SETG       :INFOptr;
   p          :pointer;

BEGIN
mark(p);
new(setg);
setwindow(36,10,78,18);
WRITEln;
WRITE('What ASCII file? : ');READLN(NAME);
writeln;
IF NOT EXIST2(NAME) THEN  BEGIN
  WRITE('Data file does not exist ...');
  PAUSE:=READKEY;
  writeln;
  EXIT;
END
ELSE BEGIN  (* if the ascii file exists *)
  ASSIGN(FIL,NAME);
  RESET(FIL);
  setg^.SIZE := 0;
  WHILE NOT EOF(FIL) DO BEGIN
    setg^.SIZE:=setg^.SIZE+1; (* increment number of data points *)
    READLN(FIL,setg^.DATA[setg^.SIZE]);
  END;
CLOSE(FIL);
WRITE('New file name? : ');READLN(setg^.NAME);
SAVE(setg^); (* save the data to a disk file of ".set" type *)
END;
```

```
window(1,1,80,25);
release(p);
END;



PROCEDURE WRITASCII;
(* this writes a data ".set" file to a single column ascii file *)
TYPE
  FYL = TEXT;

VAR
   X,Y,Z :INTEGER;
   FIL   :FYL;
   GO    :WORRD;
   name  :filename;
   SETG  :infoptr;
   p     :pointer;
BEGIN
mark(p);
new(setg);
setwindow(36,10,78,18);
READIN(setg^);
IF NOT EXIST(setg^.NAME) THEN  EXIT;
WRITE('Name of new file : ');READLN(NAME);
writeln;
ASSIGN(FIL,NAME);
REWRITE(FIL);
for x:= 1 to setg^.SIZE do
  WRITELN(FIL,setg^.DATA[X]:12:5);
CLOSE(FIL);
window(1,1,80,25);
release(p);
END;



PROCEDURE REEDKEY;
(* this procedure allow the user to enter data from the keyboard *)
(* into a '.set' file                                            *)
VAR
  code,QUIT,X,Y,FYLE : INTEGER;
  OVER           : char;
  TEMPNAME       : WORRD;
  temp           : string15;
  temp2          : double;
  setg           : infoptr;
  p              : pointer;
label 10;
BEGIN
  mark(p);
  new(setg);
  setwindow(36,10,78,18);
  writeln;
  WRITE('Name your data (',SETNAME,') : ');READLN(TEMPNAME);
  IF TEMPNAME <> '' THEN (* if a name was entered use it , otherwise use the default name *)
    SETNAME:=TEMPNAME;
  setg^.NAME:=SETNAME;
  IF EXIST(setg^.name) THEN  begin
    writeln;
    WRITE('File Exists, Overwrite?: ');
    OVER := READKEY;
    writeln;
  end
  ELSE
    OVER:='Y';
  IF UPCASE(OVER)='Y' THEN
  BEGIN
      writeln;
```

```
      WRITE('Enter "q" when done.');
      QUIT:=0;
      X:=0;
      WHILE QUIT=0 DO
      BEGIN
        X:=X+1;
     10:WRITEln;
        WRITE('Enter ELEMENT [',X,']: ');READLN(TEMP);
        (* reading a character variable and converting to a real number *)
        (* keeps the program from bombing if a data entry error is made *)
        val(TEMp,TEMP2,code);
        if code=0 then begin
          (* if the text was successfully converted to a number *)
          setg^.DATA[X]:=TEMP2;
          setg^.SIZE:=X;
        END
        else if upcase(temp[1])='Q'then quit:=1
        (* when the user enters a "q" the program will stop    *)
        (*    promting for data points and save the data file  *)
        else begin
          beep;
          goto 10;
        end;
      END;
      save(setg^);
  END;
  release(p);
END;



PROCEDURE CHANGE;
(* This procedure allows you to change a vaule in the data set.           *)
(* It is much easier to write and ascii file, edit it, and read it back in *)
VAR
  code,X,Y     : INTEGER;
  temp         : string15;
  temp2        : double;
  SAIV,CHANJ   : char;
  setg         : infoptr;
  p            : pointer;
BEGIN
mark(p);
new(setg);
setwindow(36,10,78,18);
READIN(setg^);
IF not EXIST(setg^.name) THEN exit;
  CHANJ:='Y';
  WHILE upcase(CHANJ)='Y' DO
  BEGIN
    writeln;
    WRITE('Change something?: ');CHANJ:=READKEY;
    writeln;
    writeln;
    IF upcase(chanj)='Y'  THEN
      BEGIN
        write('Which element? : ');intREAD(X);
        writeln;
        WRITE('Old value = ',setg^.DATA[X]);
        writeln;
        write('New value = ');doubleread(setg^.data[x]);
        writeln;
        write('Save the data?: ');SAIV:=READKEY;
        writeln;
        writeln;
        IF UPCASE(SAIV)='Y' THEN
        BEGIN
```

```
          WRITE('Name the data : ');READLN(setg^.NAME);
          writeln;
          SAVE(setg^);
        END;
      END;
  END;
release(p);
END;



PROCEDURE SEE;
(* This writes a data set to the screen *)
VAR X,Y     :INTEGER;
    setg    :infoptr;
    p       :pointer;
BEGIN
  mark(p);
  new(setg);
  setwindow(36,10,78,18);
  readin(setg^);
  IF not EXIST(SETg^.name) THEN exit;
  window(1,1,80,25);
  CLRSCR;
  FOR X := 1 TO setg^.size DO
    WRITE(SETG^.DATA[X]:8:4);
  PAUSE:=READKEY;
  release(p);
END;



PROCEDURE SORTHR (VAR SETG:INFO);
(* this is a heapsort for sorting values within a data set     *)
(* This was lifted ver batum from Pascal Programmers Library   *)
(* with the exception of the line before the "L9:" label, I    *)
(* had to add this to stop the procedure from trying to access *)
(* a data set element at the zero index (causes an error)      *)
LABEL  L1,L2,L3,L4,L5,L7,L8,L9;
VAR    I,J,L,R,PAUSE      :INTEGER;
       NUM                :double;
       base               :char;
BEGIN
    IF SETG.SIZE <= 1 THEN EXIT;
L1: L:=SETG.SIZE DIV 2 + 1;
    R:=SETG.SIZE;
L2: IF L > 1 THEN
      BEGIN
        L := L - 1;
        NUM := SETG.DATA[L];
      END
    ELSE
      BEGIN
        NUM :=SETG.DATA[R];
        SETG.DATA[R]:=SETG.DATA[1];
        R:= R - 1;
        IF R = 1 THEN
          BEGIN
            SETG.DATA[1]:=NUM;
            EXIT
          END
      END;
L3: J := L;
L4: I:= J;
    J:=J+J;
    IF J>R THEN GOTO L8;
    IF J=R THEN GOTO L7;
L5: IF SETG.DATA[J] < SETG.DATA[J+1] THEN
      J:=J+1;
```

```
L7: SETG.DATA[I]:=SETG.DATA[J];
    GOTO L4;
L8: J := I;
    I:= J DIV 2;
    if I<1 then I:=1;
L9: IF (NUM <= SETG.DATA[I]) OR (J = L) THEN
      BEGIN
        SETG.DATA[J] := NUM;
        GOTO L2
      END
    ELSE
      BEGIN
        SETG.DATA[J] := SETG.DATA[I];
        GOTO L8
      END;
END;



procedure quantiles;
(* This routine gets point estimates and 90% two-sided confidence intervals *)
(* for the quantiles with multiples of 10 ie. .1,.2,.3 etc.  See Kliejnen.  *)
var setg   :infoptr;
    T      :pointer;
    p,n,q  :double;

begin
  mark(T);
  new(setg);
  setwindow(36,10,78,18);
  READIN(setg^);
  if (not EXIST(setg^.name)) or (setg^.SIZE <= 20) THEN begin
    write('Insufficient sample size (<20)'); (* ASSUMPTIONS DEPEND ON N>20 *)
    pause:=readkey;
    release(T);
    exit;
  end;
  n:=setg^.size;
  writeln;
  write(' Please wait -- Sorting ...');
  sorthr(setg^);
  window(1,1,80,25);
  clrscr;
  setwindow(10,5,70,22);
  writeln('    Quantile Estimation and 90% Confidence Intervals');
  writeln;
  coloroncolor(blue,black);
  writeln('       %              Point           Lo                 Hi');
  writeln('   ____________________________________________________________');
  coloroncolor(white,black);
  writeln;
  for x:= 1 to 9 do begin (* SEE KLEIJNEN PAGE 36 FOR ALGOTITHM DISCUSSION *)
    p:=x/10;
    q:=1-p;
    write('    ',x*10:3,'%     ',setg^.data[trunc(x/10*n)]:13:2);
    write(setg^.data[trunc(n*p-1.645*sqrt(n*p*(1-p)))+1]:13:2,'     ');
    writeln(setg^.data[trunc(n*p+1.645*sqrt(n*p*(1-p)))+1]:13:2);
  end;
  writeln;
  p:=0.25;
  repeat
    q:=1-p;
    write('    ',p*100:3:0,'%     ',setg^.data[trunc(p*n)]:13:2);
    write(setg^.data[trunc(n*p-1.645*sqrt(n*p*(1-p)))+1]:13:2,'     ');
    writeln(setg^.data[trunc(n*p+1.645*sqrt(n*p*(1-p)))+1]:13:2);
    p:=p+0.5;
  until p>0.75;
  pause:=readkey;
  release(T);
```

```
end;



Procedure Probability;
(* This routine uses the estimator for binomial probabilities to get a       *)
(* nonparametric estimation of the probability of a value drawn from the     *)
(* data set s underlying population begin less than X.  The estimator        *)
(* and CI formulas can be found in any basic stats book.  I used Elementary *)
(* Statistics by Duxbury.                                                      *)
var setg                      :infoptr;
    T                         :pointer,
    Lo,Hi,sum,number,p,q      :double;
    n                         :integer;

begin
  mark(T);
  new(setg);
  setwindow(36,10,78,18);
  READIN(setg^);
  if (not EXIST(setg^.name)) or (setg^.SIZE <= 20) THEN begin
    write( Insufficient sample size (<20) ); (* assumption of N>20 *)
    pause:=readkey;
    release(T);
    exit;
  end;
  writeln( Function returns P(x<X) );
  write( Enter X: ');doubleread(number);
  n:=setg^.size;
  writeln;
  write(  Please wait -- Sorting ...');
  writeln;
  sortbr(setg^);
  sum:=0;
  for x:= 1 to n do
    if setg^.data[x]<Number then sum:=sum+1;
  p:=sum/(n 1);
  q:=1 p;
  Lo:=p-1.645*sqrt(p*q/n);
  Hi:=p+1.645*sqrt(p*q/n);
  if (p*n < 5) or (q*n < 5) then begin        (* q*n and P*n must be > 5 *)
    write( Insufficient data spread ... );     (* for CI to hold water    *)
    pause:=readkey;
    release(T);
    exit;
  end;
  writeln;
  writeln( Point estimate:  ,p:7:5);
  writeln( 90% CI:     Hi : ',Hi:7:5);
  writeln(             Lo : ',Lo:7:5);
  pause:=readkey;
  release(T);
end;

end.
```

```
{$M 64000,0,655000}
{N+}  (* sets the coprocessor on *)
Unit daveMenu;

(**************************************************************************

This unit contains all the Procedures necessary to support the scrolling
menus in the main program.  The menu choices and attributes are stored
in MENU which is a record.  Notice that this is a pointer variable, meaning
that this variable resides in the HEAP, leaving the whole 64K of main data
memory free for the application (main program).  Also note that this is a
global variable, eliminating the need to pass it as a parameter among the
various Procedures, which would overload the stack section of memory.

**************************************************************************)



INTERFACE
Uses
  Crt,
  Dos;

type

  String30=string[30];
  String15=string[15];
  ScreenPtr=^Screentype;
  Screentype=Record                                    (***********************)
               Pos : ARRAY[1..25,1..80] OF RECORD     (* This enables storing *)
                   Ch : CHAR;                          (* a text Screen to     *)
                   At : BYTE;                          (* memory for later use.*)
                   End;                                (*                      *)
               CursX,CursY : integer;                  (***********************)
               End;

  MenText=array [0..11,1..10] of string30;
  MenPos=array [1..2,0..9,1..10] of integer;
  MenFirst=array [1..10] of boolean;
  MenScreen=array [1..10] of Screentype;
  MenInfoPtr =^menInfo;
  MenInfo = record
             text:mentext;
             pos :menpos;
             First:menFirst;
             Screen:menScreen;
             max:array [1..10] of integer;
             top:array [1..10] of integer;
             left:array [1..10] of integer;
           End;

  FileName = STRING[12];
  Worrd     = STRING[8];


VAR
  x                                          : integer;
  Screen                                     : ScreenPtr;
  Menu                                       : MenInfoPtr;
  pause                                      : Char;


Procedure ColorOnColor(letters,back:word);
Procedure Beep; (* original *)
Procedure DoubleRead(var value:double);
Procedure IntRead(var value:integer);
Procedure GenericBox(x1,y1,x2,x3,x4,y4,LineType:integer);
Procedure SetWindow(y1,x1,y2,x2:integer);
```

```
Procedure HorzSetMenu(wich:integer);
Procedure ScrollMenu(wich:integer;var go,go2:char;var temp:integer);
Procedure Highlight(xpos,ypos,choice,wich:integer);
Procedure MenuControl(wich:integer;var go,go2:char;var temp:integer);
Procedure ShowDir(FileSpec:FileName);  (* turbo 4.0 or pascal programmers library *)
Procedure Prtsc;

IMPLEMENTATION



Procedure Prtsc;  (* from Pascal Programmers Library, By Que *)

(***********************************************************
This Procedure forces a screen dump to the printer when in the
text mode, and will work in the graphic mode if a graphic screen
dump utility such as egadmp of the CHART package, has been
installed.
***********************************************************)

Var Reg:Registers;
Begin
  Intr($5,Dos.Registers(REG))
End;



Procedure ShowDir(FileSpec:FileName);

(***********************************************************
This Procedure displays a directory of the current disk using the
file specification given, such as *.* or *.pas. Taken from the
Que book Turbo Pascal Programmers Library.
***********************************************************)

type
  String80 =string[80];
const Columns = 5;
VAR   J,ColSize :integer;
      Reg       :registers;
      Dta       :ARRAY[1..43] OF BYTE;
      Attr      :BYTE;
      Pause     :CHAR;
Begin
  CLRSCR;
  ATTR:=0;
  COLSIZE := 80 DIV COLUMNS;
  REG.DX :=OFS(DTA);
  REG.DS := SEG(DTA);
  REG.AX := $1A00;
  MSDOS(Dos.Registers(REG));
  ColorOnColor(yellow,blue);
  gotoxy(24,1);writeln('**********  DIRECTORY  **********');
  TextBackground(black);
  writeln;
  FileSpec := FileSpec + CHR(0);
  REG.DX := OFS(FileSpec[1]);
  REG.DS:= SEG(FileSpec[1]);
  REG.CX:=ATTR;
  REG.AX:=$4E00;
  MSDOS(Dos.Registers(REG));
  IF LO(REG.AX) <> 0 THEN
   Begin
     writeln ('NO SET FILES FOUND');
     PAUSE:=READKEY;
     EXIT;
   End;
```

```
  IF DTA[22] AND $10 <> 0 THEN WRITE ('[D]');
  J := 31;
  WHILE DTA[J] <> 0 DO
    Begin
      WRITE(CHR(DTA[J]));
      J := J+1
    End;
  REPEAT
    REG.DX := OFS(DTA);
    REG.DS := SEG(DTA);
    REG.AX := $4F00;
    MSDOS(Dos.Registers(REG));
    IF LO(REG.AX) = 0 THEN
      Begin
        IF WHEREX > (COLUMNS -1 ) * COLSIZE +1 THEN writeln;
        WHILE (WHEREX MOD COLSIZE) <> 1 DO WRITE (' ');
        IF DTA[22] AND $10 <> 0 THEN WRITE ('[D]');
        J := 31;
        WHILE DTA[J] <> 0 DO
          Begin
            WRITE (CHR(DTA[J]));
            J := J+1
          End;
      End;
    UNTIL LO(REG.AX) <> 0;
    writeln;
    PAUSE:=READKEY;
  End;


Procedure ColorOnColor(letters,back:word);

(**************************************************************************
this allows the programmer to change the text color and the background
color with one statement.
***************************************************************************)

Begin
textcolor(letters);
TextBackground(back);
End;


Procedure Beep;
Begin
sound(500);
delay(250);
nosound;
End;


Procedure DoubleRead(var value:double);

(**************************************************************************
This procedure does error checking while reading in double precision numbers.
It keeps the program from aborting if the number is entered imporperly.
***************************************************************************)

var temp : FileName;
    code : integer;
label 10;
Begin
10:readln(temp);
val(temp,value,code);
  if (code<>0) then Begin
    Beep;
    write('Re-enter the value: ');
```

```
    goto 10;
  End;
End;



Procedure IntRead(var value:integer);

(*************************************************************************
This procedure does error checking while reading in integer numbers.
It keeps the program from aborting if the number is entered improperly.
*************************************************************************)

var temp : FileName;
    code : integer;
label 10;
Begin
10:readln(temp);
writeln;
val(temp,value,code);
  if (code<>0) then Begin
    Beep;
    write('Re-enter the value: ');
    goto 10;
  End;
End;



Procedure GenericBox(x1,y1,x2,x3,x4,y4,LineType:integer);

(*************************************************************************
This procedure draws a box starting at the x1,y1 positon, ending at the
x4,y4 position. Horizontal dividers are drawn at positions x2 and x3 if they
are set to something other than zero.  Allows for drawing with single or double
lines, or a mix of both.
*************************************************************************)

type
   bar = string[79];
var
  lyne,lyne2 : bar;
  hl,hl2,vl,ul,ur,ll,lr,li,ri,ti,bi,mi:char;
  X:integer;
Begin
window(y1,x1,y4,x4);
clrscr;
window(1,1,80,25);
if LineType=1 then Begin
  ul:=#218;
  hl:=#196;
  ur:=#191;
  vl:=#179;
  ll:=#192;
  lr:=#217;
  rI:='┤';
  lI:='├';
End
else if LineType=3 then Begin
  HL:=#205;
  hl2:=#196;
  UR:=#187;
  UL:=#201;
  LR:=#188;
  LL:=#200;
  rI:=#182;
  lI:=#199;
  VL:=#186;
```

```
End
else if LineType=2 then Begin
  UL:=CHAR(201);
  HL:=CHAR(205);
  UR:=CHAR(187);
  LR:=CHAR(188);
  LL:=CHAR(200);
  rI:=CHAR(185);
  lI:=CHAR(204);
  VL:=CHAR(186);
End;
LYNE:='';
lyne2:='';
FOR X:=1 TO Y4-Y1-1 DO
  LYNE:=LYNE+HL;
if LineType=3 then for x:=1 to y4-y1-1 do
  lyne2:=lyne2+hl2
else lyne2:=lyne;
GOTOXY(y1,x1);WRITE(UL);WRITE(LYNE);
GOTOXY(Y4,X1);WRITE(UR);
FOR X:= X1+1 TO X4 DO
  Begin
  GOTOXY(Y1,X); WRITE(VL);
  GOTOXY(Y4,X); WRITE(VL);
  End;
IF X2<>0 THEN Begin
  GOTOXY(Y1,X2);WRITE(LI);WRITE(LYNE2);
  GOTOXY(Y4,X2);WRITE(RI);
End;
IF X3<>0 THEN Begin
  GOTOXY(Y1,X3);WRITE(LI);WRITE(LYNE2);
  GOTOXY(Y4,X3);WRITE(RI);
End;
GOTOXY(Y1,X4);WRITE(LL);WRITE(LYNE);
GOTOXY(Y4,X4);WRITE(LR);
End;


Procedure SetWindow(y1,x1,y2,x2:integer); (* turbo 4.0 documentatin *)

(***************************************************************************
This procedure draws a box in the specified region and clears it for a pop-
up window.
***************************************************************************)

var i:integer;
Begin
window(y1-1,x1-1,y2+1,x2+1);
clrscr;
window(1,1,80,25);
textcolor(blue);
GenericBox(x1-1,y1-1,0,0,x2+1,y2+1,2);
window(y1,x1,y2,x2);
ColorOnColor(white,black);
End;


Procedure HorzSetMenu(wich:integer);

(***************************************************************************
This procedure sets the positions for each line of text for a menu screen.
The coordinates are detirmined by the top of menu, left edge of menu, and
how many choices are on the menu.
***************************************************************************)

var x:integer;
```

```
Begin
  for x:= 1 to Menu^.max[wich] do Begin
    Menu^.pos[2,x,wich]:=x+3+Menu^.top[wich];
    Menu^.pos[1,x,wich]:=Menu^.left[wich]+2;
  End;
  Menu^.pos[2,0,wich]:=Menu^.pos[2,Menu^.max[wich],wich]+2;
  Menu^.pos[1,0,wich]:=Menu^.left[wich]+2;
End;



Procedure horzdrawMenu(wich:integer);

(*************************************************************************
This procedures uses the others to draw a menu screen.
*************************************************************************)

var x:integer;
Begin
  ColorOnColor(yellow,black);
  GenericBox(Menu^.top[wich],Menu^.left[wich],Menu^.top[wich]+2,
       Menu^.max[wich]+7+Menu^.top[wich]-1,Menu^.max[wich]+9+
       Menu^.top[wich]-1,Menu^.left[wich]+18,2);
  ColorOnColor(white,black);
  TextBackground(red);
  GOTOXY(Menu^.left[wich]+2,Menu^.top[wich]+1); WRITE(Menu^.text[Menu^.max[wich]+1,wich]);
  TextBackground(black);
  for x:= 1 to Menu^.max[wich]+1 do Begin (* use x-1 to get around not letting x be zero*)
    ColorOnColor(WHITE,BLACK);
    GOTOXY(Menu^.pos[1,x-1,wich],Menu^.pos[2,x-1,wich]);WRITE(Menu^.text[x-1,wich]);
    ColorOnColor(CYAN,BLACK);
    GOTOXY(Menu^.pos[1,x-1,wich],Menu^.pos[2,x-1,wich]);WRITE(Menu^.text[x-1,wich][1]);
  End;
End;



Procedure ScrollMenu(wich:integer;var go,go2:char;var temp:integer);

(*************************************************************************
This procedure moves the highlighting bar up and down the menu as the arrow
keys are used.  It also sets the menu choice each time it moves the bar
so that when the enter key is hit the proper menu choice will be selected.
*************************************************************************)

Begin
  go:=readkey;
  if go='P' then
    if temp<Menu^.max[wich] then temp:=temp+1
    else temp:=0;
  if go='H' then
    if temp>0 then temp:=temp-1
    else   temp:=Menu^.max[wich];
  go2:=Menu^.text[temp,wich][1];
End;



Procedure Highlight(xpos,ypos,choice,wich:integer);

(*************************************************************************
This procedure writes a string of text in yellow on cyan highliting.
*************************************************************************)

Begin
  ColorOnColor(WHITE,cyan);
  gotoxy(xpos,ypos);write(Menu^.text[choice,wich]);
  ColorOnColor(white,black);
End;
```

```
Procedure MenuControl(wich:integer;var go,go2:char;var temp:integer);

(***************************************************************************
This procedure is the master control module that takes over any time the
program enters a menu procedure.  It handles the screen drawing, scrolling,
and returns the proper choice the user selected to the individual menu
procedure in the main menu, so that choice can be executed. Note that if this
particialr menu has been called once before, the screen need not be drawn
again since it was stored in memory.  The menu screen is simply recaled from
memory with the index WICH.
***************************************************************************)

Begin
    IF (Menu^.First[wich]) THEN Begin
      Menu^.First[wich]:=FALSE;
      HorzSetMenu(wich);
      horzdrawMenu(wich);
      Menu^.Screen[wich]:=Screen^;
      Highlight(Menu^.pos[1,temp,wich],Menu^.pos[2,temp,wich],temp,wich);
    End
    ELSE if (go<>'P') and (go<>'H') then Begin
      Screen^:=Menu^.Screen[wich];
      go:=Menu^.text[1,wich][1];
      GO2:=Menu^.text[1,wich][1];
      temp:=1;
      Highlight(Menu^.pos[1,temp,wich],Menu^.pos[2,temp,wich],temp,wich);
    End;
    GOTOXY(Menu^.left[wich]+10,Menu^.pos[2,0,wich]+2);
    GO:=READKEY;
    if  go=#0 then Begin
        Screen^:=Menu^.Screen[wich];
        ScrollMenu(wich,go,go2,temp);
        Highlight(Menu^.pos[1,temp,wich],Menu^.pos[2,temp,wich],temp,wich);
    End;
    if go=chr($00) then
      go:=go2;
    for x:= 1 to Menu^.max[wich]+1 do
      if upcase(go)=Menu^.text[x,wich][1] then Begin
        temp:=x;
        Screen^:=Menu^.Screen[wich];
        Highlight(Menu^.pos[1,temp,wich],Menu^.pos[2,temp,wich],temp,wich);
      End;
End;


(***************************************************************************
This initilaizes the pointer heap variables ant sets their intial values.
***************************************************************************)

Begin
new(Menu);
new(Screen);
Screen := PTR($B800,$0000);
for x:= 1 to 10 do
  Menu^.First[x]:=true;
End.
```

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MONTE CARLO METHOD, RANDOM NUMBER GENERATION

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

A tool was developed for Monte Carlo simulation of life cycle costs using parametric cost modeling. Additionally, the analysis of the performance of parametric CER cost estimation has been cut down to a more manageable task. Models can be built and tested quickly and easily.

Random deviate generators were researched and built. Several applicable statistical description routines were also implemented. Statistical integrity and great accuracy has been maintained, while made accessible through an intuitive, user friendly interface.

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